CORPS OF ENGINEERS, U. S. ARMY

SPILLWAY FOR GAVINS POINT DAM
MISSOURI RIVER, NEBRASKA

HYDRAULIC MODEL INVESTIGATION

TECHNICAL MEMORANDUM NO. 2-404

CONDUCTED FOR

OMAHA DISTRICT, CORPS OF ENGINEERS

BY

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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PREFACE

Model investigations of the spillway for Gavins Point Dam were authorized by the Office, Chief of Engineers, in the first indorsement, dated 11 February 1952, to basic letter, dated 1 February 1952, from the Missouri River Division to the Office, Chief of Engineers. Model studies were conducted in the Hydraulics Division of the Waterways Experiment Station during the period March 1952-August 1953 by Messrs. J. W. Bolin, Jr., W. H. Sadler, Jr., and W. C. Sylvester, under the general supervision of Messrs. F. R. Brown and T. E. Murphy.

Messrs. E. R. Bloomquist, E. A. Johns, W. T. Black, A. H. Bauman, and W. D. Fulton of the Omaha District and Mr. N. L. Barbarossa of the Missouri River Division visited the Waterways Experiment Station during the course of the study to discuss test results and correlate these results with design work concurrently being accomplished in the District Office.

CONTENTS

SUMMARY

Hydraulic performance of the Gavins Point spillway was studied in a 1:60-scale model.

Test results demonstrated the need for a dike at the left abutment of the spillway to improve flow conditions, and verified the adequacy of the spillway weir and stilling basin. The only change effected in the stilling basin was the reduction of end sill height from 14 ft to 9 ft.

SPILLWAY FOR GAVINS POINT DAM

MISSOURI RIVER, NEBRASKA

Hydraulic Model Investigation

PART I: INTRODUCTION

Pertinent Features of the Prototype

1. Gavins Point Dam is presently under construction across the Missouri River Valley approximately 4 miles west of Yankton, South Dakota, on the Nebraska-South Dakota line (fig. 1). The reservoir created by the dam will be one of a system of multiple-purpose reservoirs on the Missouri River for flood control, irrigation, navigation, power, and other uses. In addition, the Gavins Point Dam will serve as a re-regulating structure for flows from the Ft. Randall Reservoir located 75 miles upstream. The dam will be a rolled-fill earth and chalk embankment with a maximum height above the river channel of 75 ft and an over-all length of approximately 8700 ft. A chute spillway with a gated ogee crest will be located in the right abutment. The powerhouse also will be located in the right abutment a short distance to the right of the spillway (plate 1). The reservoir will have a total storage capacity of 540,000 acre-ft at maximum normal operating pool elevation of 1210.0*.

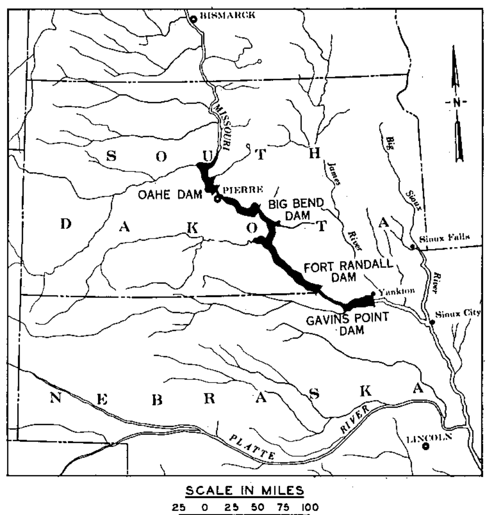

Fig. 1. Vicinity map

2. The gated-spillway structure will be straight in plan and will have a gross length of 664 ft between abutments. Flow over the weir will be controlled by 14 tainter gates, each 40 ft long and 30 ft high. Each

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* All elevations are in feet above mean sea level.

crest bay will be separated from adjacent bays by piers 8 ft in thickness, leaving a net crest length of 560 ft. The weir crest, at el 1180, will be 25 ft above the approach channel floor and is designed for a discharge of 577,300 cfs under a head of 41.0 ft. Design flood-control pool elevation is 1221.6.

3. A paved chute, 664 ft wide and 216 ft long, will connect the weir and the stilling basin. The chute will slope downstream on a 3 per cent grade in the upper 100 ft and on a 25 per cent grade in the lower 116 ft. Circular curves will connect the weir to the chute and the chute to the stilling basin floor. The upstream end of the chute will be at el 1155 and the downstream end will terminate at the stilling basin floor, el 1123. The chute will be flanked on either side by concrete training walls which will confine the flow.

4. The stilling basin will be of the hydraulic-jump type consisting of a horizontal apron surmounted by two rows of baffle piers and terminated by an end sill. The apron will be at el 1123 and, at the design discharge and advanced-degradation tailwater, will provide 86 per cent of the theoretical depth (D_2) required for a hydraulic jump. The length of the apron will be 220 ft, which is about 3.6 times D_2. For details of the weir, chute, and stilling basin, see plates 2 and 3.

5. The powerhouse ultimately will have three generating units of the turbine type designed for a dependable capacity of 87,000 kw.

Purpose of Model Analysis

6. Although the hydraulic design of the Gavins Point Dam spillway presented no unique problems, model investigations were considered desirable in the interest of safety and economy. The model provided a means for study of general flow conditions, determination of wall heights, investigation of the energy dissipation characteristics of the stilling basin, and study of erosion protection requirements.

PART II: THE MODEL

Description

7. The model of the Gavins Point Dam spillway was constructed to an undistorted scale ratio of 1:60 (fig. 2 and plate 1) and reproduced about 1530 ft of the approach channel upstream from the dam, the entire spillway, a portion of the dam, the powerhouse structure (schematically), and about 2520 ft of the exit area downstream from the spillway. The approach channel and the nonoverflow section of the dam were molded in concrete to metal templets. The spillway crest section was formed of stainless-steel sheets fastened to accurately shaped sheet-metal templets, and was surmounted with crest piers constructed of wood and plastic. The spillway chute and stilling basin were fabricated of aluminum sheets placed on metal and wood supports. The powerhouse was reproduced schematically of wood. The exit area was capped with a thin

Fig. 2. Details of model

layer of cement mortar during velocity measurements. During erosion tests the portion of the exit area under study was molded in sand.

Model Appurtenances and Their Application

8. Water used in the operation of the model was supplied by centrifugal and axial-flow pumps connected in a manner that permitted flexibility of operation. The water was drawn from a large sump, and measured by means of venturi meters. The flow from the supply line discharged into a headbay where it was stilled by baffles prior to its entrance into the model. After passing through the model, the water returned to the supply sump through a gravity return line. Tailwater elevations in the lower end of the model were adjusted by means of a tailgate operated by a worm gear hoist. Steel rails set to grade alongside the model provided a datum plane for measuring devices. Water-surface elevations were measured by means of a point gage mounted on an aluminum channel supported by the above-mentioned steel rails, and by means of piezometers. Velocities were measured with a pitot tube. All velocities presented, except those used for velocity head corrections in the determination of gross head, are average surge velocities and in general are about one-third greater than average velocities. Pressures on the spillway weir and against the piers were measured in manometers connected by tubes to piezometer openings in the model. Soundings over the sand bed downstream from the stilling basin were taken with a portable sounding rod. Certain of the flow conditions in the model were recorded photographically.

Scale Relationships

9. The requirements for geometric and dynamic similarity between model and prototype were satisfied by constructing all elements of the model to an undistorted linear scale ratio, and by testing all hydraulic quantities in their proper relationships as derived from Froude's law. General scale relationships for transference of model data to prototype equivalents, and vice versa, were as follows:

Dimension	Ratio	Scale Relationship
Length	L_r	1:60
Velocity	$V_r = L_r^{1/2}$	1:7.746
Time	$T_r = L_r^{1/2}$	1:7.746
Discharge	$Q_r = L_r^{5/2}$	1:27,888

All data obtained on the model have been transferred to prototype equivalents by means of the preceding scale relationships and, except evidences of scour, may be accepted quantitatively. Scour data must be accepted as reliable only in a qualitative sense.

PART III: NARRATIVE OF TESTS

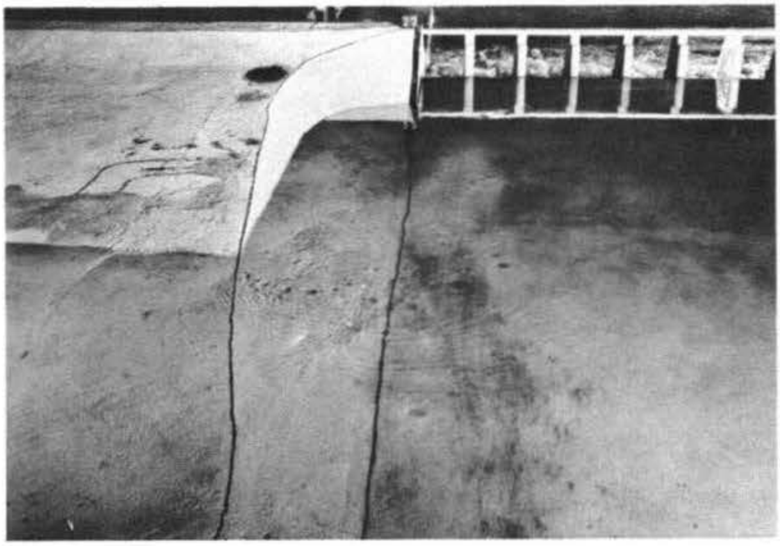
Spillway Approach

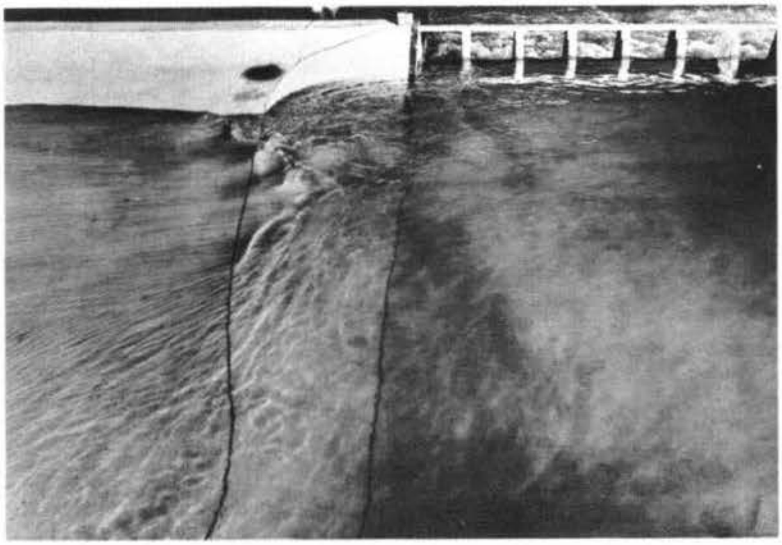
10. The floodplain immediately upstream from the spillway has a surface elevation of approximately 1176. A relatively short (650 ft) approach channel will be excavated to el 1155 for the entire width of the spillway weir. A diversion channel with a bottom width of 240 ft will connect the approach channel with the main river channel. Extent of the approach channel and alignment of the diversion channel are shown on plate 1.

11. Flow conditions in the reservoir and approach channel were satisfactory except on the left side of the spillway along the upstream face of the embankment, and in the immediate vicinity of the right abutment to the spillway.

12. On the left side of the spillway, lateral flow swept along the upstream face of the embankment and, as it entered the spillway approach channel, created an area of severe turbulence (fig. 3). Design engineers of the Omaha District stated that chalk excavated from the spillway area could be made available to form a cutoff dike at this abutment. Therefore, a series of model tests was conducted to determine the optimum location and size for the dike. In order to facilitate revisions, the model dike was first constructed of pea gravel. This permitted the dike to be modified while flow was passing through the model. After a satisfactory alignment had been developed, the dike was fixed in the model with a crust of cement mortar and final data were obtained. Initially the top of the dike was constructed at el 1212 (2 ft above normal operating pool), but later tests were conducted with the top of the dike raised to el 1222 (0.4 ft above the elevation of the design flood pool). The dike as developed by the model tests is shown on plate 4. This dike successfully reduced the currents along the upstream face of the embankment (fig. 4); and, although it did not entirely eliminate eddy action and turbulence along the left bank of the approach channel, it did produce satisfactory alignment of currents in the immediate vicinity of

Discharge, 100,000 cfs
Pool elevation, 1193.7





Discharge, 330,000 cfs
Pool elevation, 1209.1

Discharge, 613,800 cfs
Pool elevation, 1222.9

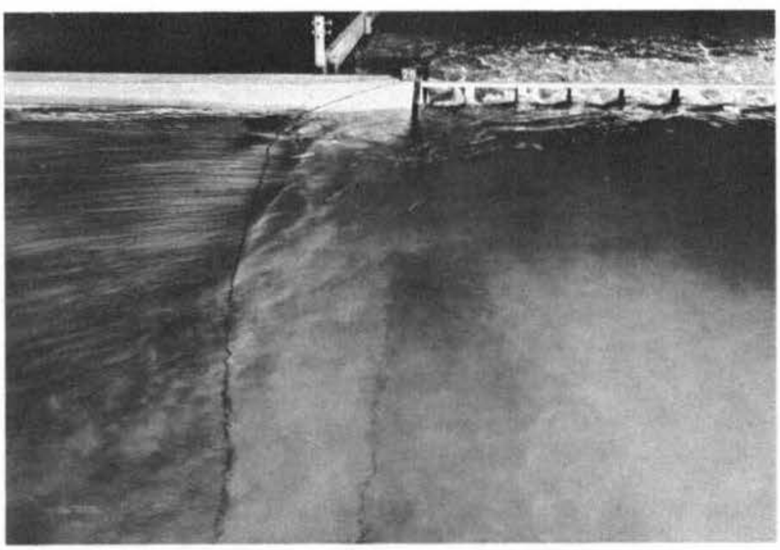
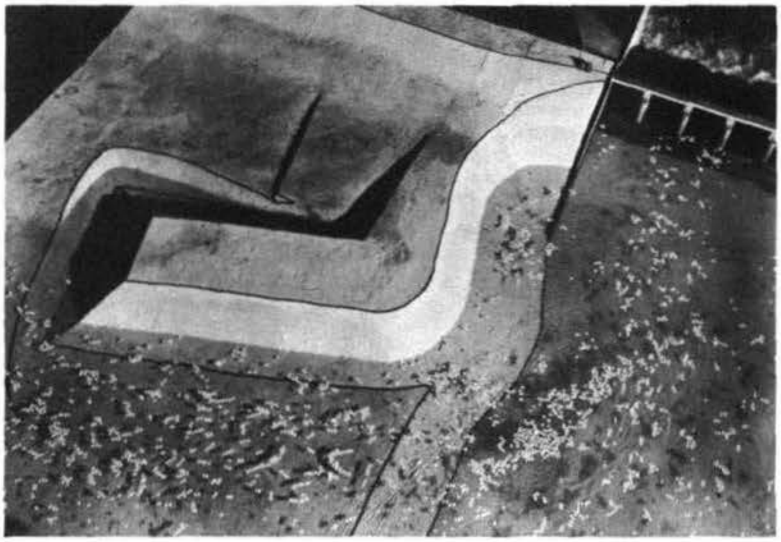
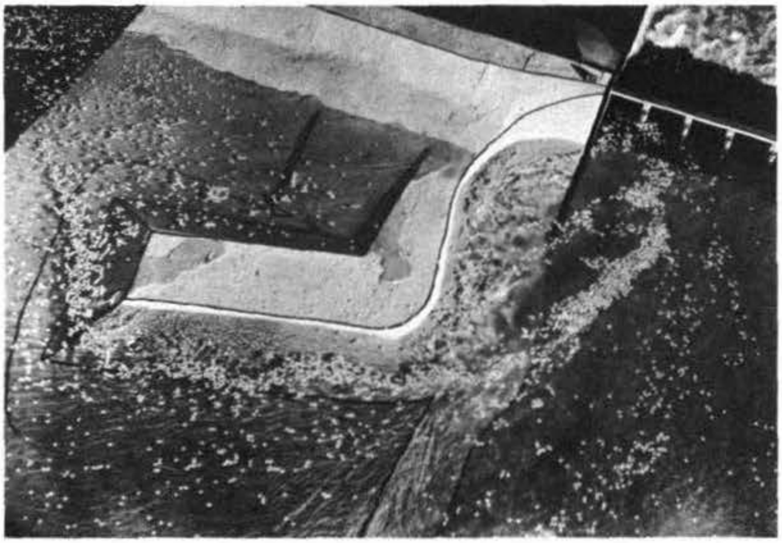


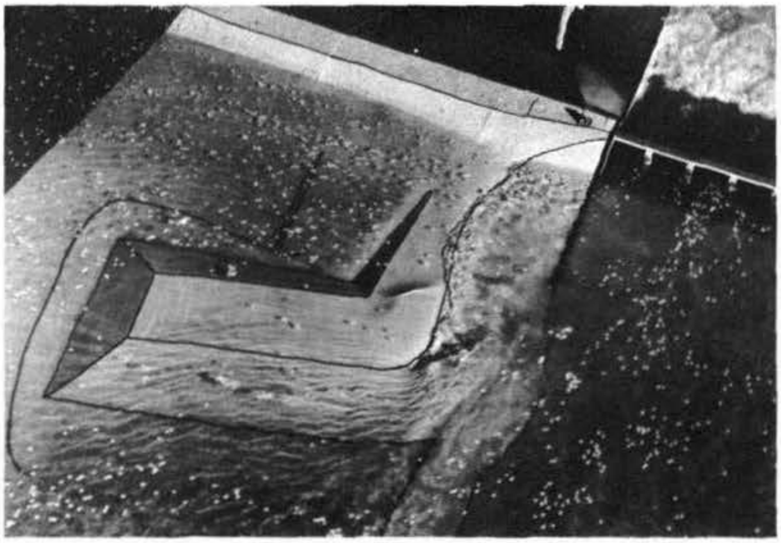
Fig. 3. Flow at left abutment, original design



Discharge, 100,000 cfs
Pool elevation, 1193.7



Discharge, 364,000 cfs
Pool elevation, 1211.0



Discharge, 626,000 cfs
Pool elevation, 1223.5

Fig. 4. Flow at left abutment. Chalk dike installed

the spillway weir (plates 5-7). The improvement in flow conditions at the weir resulted in increased capacity (plate 9). All subsequent tests were conducted with the dike installed in the model.

13. Turbulence at the right abutment was not severe, but there was considerable drawdown as flow passed around the abutment and entered the first gate bay. A vertical, curved wall extending from the right abutment into the approach channel (plate 8) was tested and improved flow conditions (fig. 5). However, the effect of this improvement was

Original design

Alternate wall

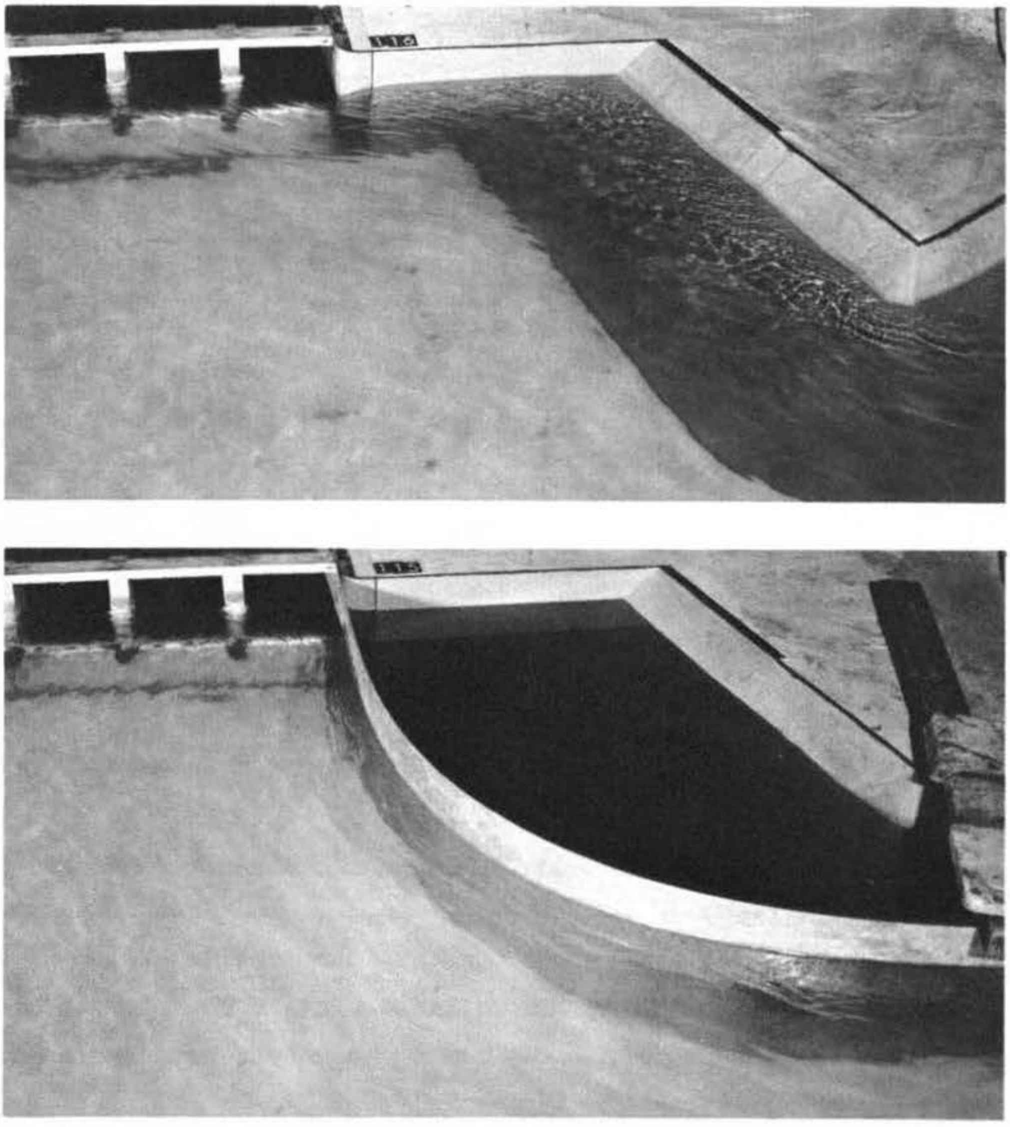


Fig. 5. Flow at right abutment
Discharge, 586,000 cfs; pool elevation, 1221.6

not sufficient to be detected in measurements of the capacity of the weir, and the wall was omitted from further consideration.

Weir

14. The upstream face of the 25-ft-high spillway weir sloped 3 on 2. The profile of the weir crest was shaped to conform with the lower nappe of a sheet of water flowing over a sharp-crested weir under a head of 41.0 ft. Details of the weir and crest piers are shown on plate 3 and were described previously in paragraph 2.

15. Calibration data (plate 9) contained in this report are based on the gross head at the center line of the approach channel 410 ft upstream from the crest of the weir. Velocity heads at this location for a complete range of discharges with all spillway gates open are presented on plate 10. Actual distribution of flow in the approach channel 125 ft upstream from the crest of the weir is given in table 1. In order to determine the coefficient of discharge C for the spillway weir, the piers were removed and head-discharge relationships measured. A coefficient of about 3.95 was obtained at the design head (41 ft). The losses at the two abutments are included in this coefficient. Head-discharge relationships also were determined with the crest piers installed and values of the pier contraction coefficient K were computed using the weir coefficients previously obtained. These values ranged from 0.045 at a head of 15 ft to 0.006 at the design head, 41 ft. Plots of C and K values are presented on plate 11.

16. Pressure conditions on the weir and piers were generally satisfactory (plate 12 and tables 2 and 3). There were indications of an area of negative pressure along the intersection of the weir and pier immediately following the bulkhead slot in the pier (piezometers 22 and 32). However, since the minimum pressure measured in this area was only -9 ft, cavitation is unlikely.

17. Water-surface elevations over the weir and in the upper portion of the chute for a range of discharges are presented in tables 4-6.

Chute

18. A paved chute 664 ft wide and 216 ft long will connect the weir and the stilling basin (plate 2). The chute walls will have a 4-to-1 batter and the minimum wall height will be controlled by the design features of the abutment and stilling basin.

19. Tests revealed that although the relatively short spillway crest piers with abruptly terminated downstream noses created standing waves in the chute for all flow conditions, the freeboard on the chute walls was adequate (fig. 6). No tests were directed toward reduction of these standing waves.

Fig. 6. Height of chute walls was adequate for maximum flow in chute. Discharge, 626,000 cfs; pool elevation, 1223.5; and tailwater elevation, 1176.3

Discharge Channel

20. Installations downstream from Gavins Point Dam make it desirable that spillway flows remain against the right side of the valley.

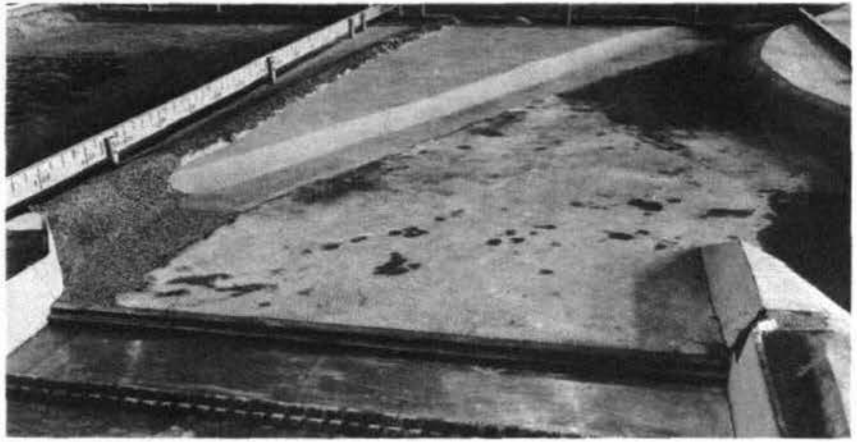
Thus, plans provide for a chalk dike extending about 3300 ft downstream from the left end of the stilling basin, and a pilot channel cut through the overburden against the right bank (plate 1). It is expected that spillway flows will erode all overburden between the chalk dike and right bank as far downstream as the end of the chalk dike.

21. Prior to tests of the stilling basin, a series of tests was conducted in the model to furnish an indication of (a) the manner in which the overburden could be expected to erode, and (b) velocities to which the base rock and chalk dike would be subjected after erosion. For these tests, areas on the right side of the channel representing rock were fixed with a crust of cement mortar; on the left side of the channel the chalk dike and rock areas were molded in pea gravel; all overburden material was simulated by sand. Testing procedures consisted of passing successive discharges of 100,000, 300,000, and 364,000 cfs through the model with the tailwater progressively lowered from the elevations defined by the 1949-1950 rating curve (plate 13) to the advanced degradation rating curve. After all overburden had been eroded, bottom velocities were measured throughout the exit channel.

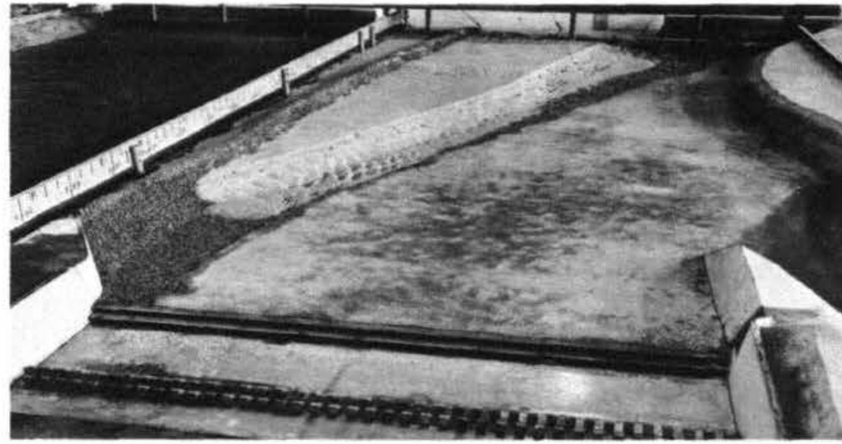
22. The progressive erosion of the exit channel by the above-mentioned discharges is depicted on fig. 7. Although the chalk dike was subjected to considerable wave action, there was no direct current attack upon the dike. Bottom velocities in the eroded exit channel are plotted on plates 14-17.

Stilling Basin

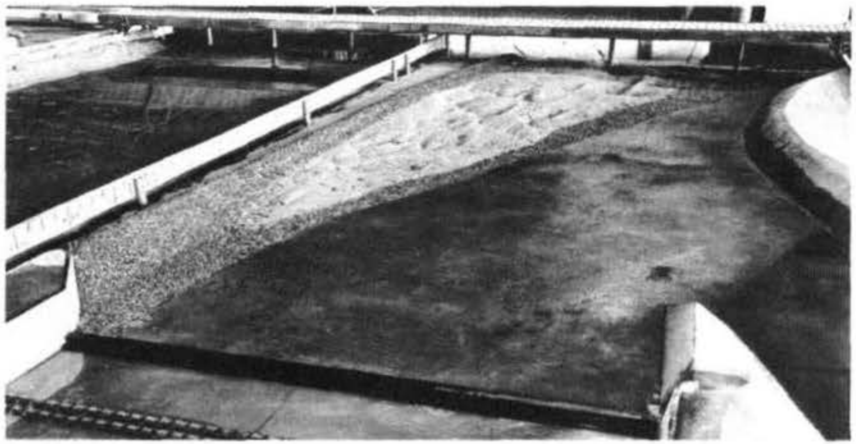
23. Model investigation of the stilling basin consisted of observations of flow conditions, measurements of velocities at the end of the basin, and determination of scour characteristics in the exit channel below the basin. For scour tests the floor of the exit channel was molded in sand to el 1140. Where the top of the end sill was at an elevation below 1140, the sand was sloped at the rate of 1 on 10 from the top of the end sill to el 1140. Comparative tests were conducted at a discharge of 364,000 cfs and a tailwater elevation of 1170.2 (advanced



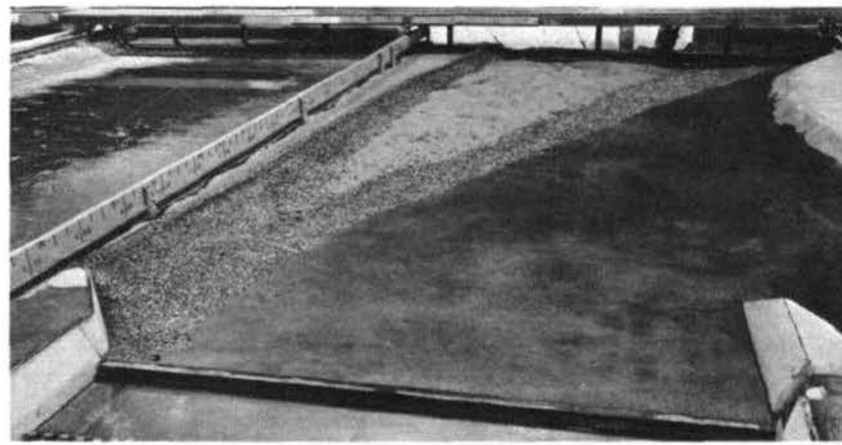
Prior to test



Discharge, 100,000 cfs; tailwater elevation, 1172.6 to 1159.8 after 1 hr, 15 min



Discharge, 300,000 cfs; tailwater elevation, 1173.9 to 1168.5 after 2 hr, 25 min (total)



Discharge, 364,000 cfs; tailwater elevation, 1170.2 after 3 hr, 25 min (total)

Fig. 7. Erosion of exit channel

degradation). No data are presented on certain types of stilling basins investigated where no improvement in basin performance was effected.

Original stilling basin (type 1)

24. The stilling basin of original design (type 1) had a length of 220 ft from the point of intersection of the circular curve that connected the chute and apron to the downstream face of the end sill. The floor of the basin was at el 1123 and was surmounted by two rows of 8-ft-high baffle piers located 69 and 87 ft downstream from the beginning of the basin. The basin was terminated by a two-stepped end sill 14 ft high. Details of the basin except for the end sill are shown on plate 2.

25. Satisfactory hydraulic-jump action obtained in the stilling basin of original design for complete ranges of discharge and tailwater elevation (fig. 8). The effect of tailwater variation on bottom velocities over the end sill was very slight throughout the range of expected tailwater (plate 18). Also, distribution of flow over the end sill was good with maximum velocities near the surface (plate 19). A test of one-hour duration indicated scour to be greatest in the center of the channel about 100 ft downstream from the end sill; slightly deeper scour holes formed along the sides of the channel (plate 20).

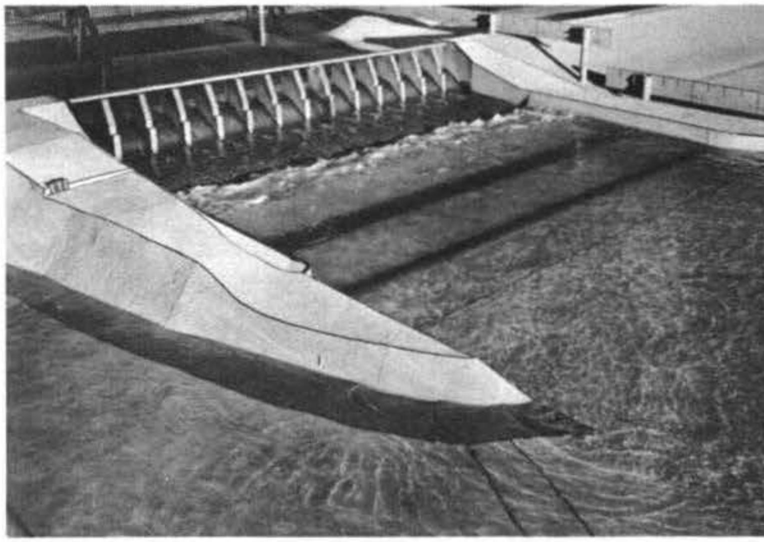
Need for baffle piers

26. The effect of baffle piers in the development of good stilling action was determined by tests conducted with baffle piers removed from the original design stilling basin (type 1-A stilling basin). Removal of the baffle piers resulted in an undesirable distribution of flow over the end sill with maximum velocities near the bottom which were about 20 per cent greater than those that obtained with the original design (compare lower plot on plate 21 with center plot on plate 19). Also a scour test produced a hole in the center of the channel about 30 ft deep (plate 22) as opposed to 20 ft deep with the original design.

Height of end sill

27. The baffle piers were reinstalled on the apron and the height of the end sill reduced from 14 ft to 9 ft to form the type 1-B stilling basin. Reduction in the height of the end sill produced no

Discharge, 100,000 cfs
Tailwater elevation,
1159.8



Discharge, 364,000 cfs
Tailwater elevation,
1170.2

Discharge, 626,000 cfs
Tailwater elevation,
1176.3

Fig. 8. Original design stilling basin

noticeable changes in general flow characteristics, and maximum velocities at the end sill were about the same as for the original design; bottom velocities at the end sill were reduced by about 30 per cent (compare center plots of plates 21 and 19). Bottom velocities over the end sill were only slightly affected by variations in tailwater throughout the expected range (plate 23). Scour was approximately the same as obtained with the original design stilling basin (compare plate 24 with plate 20).

Location of baffle piers

28. In the original design the two rows of baffle piers were spaced 18 ft apart, front face to front face. Since the baffles were 15 ft long, this left a clear space of only 3 ft between rows. Tests were conducted with the second row moved 12 ft downstream, providing a clear distance between the rows equal to the length of a baffle pier (type 1-C stilling basin). Test results indicated that increasing the distance between the two rows of baffle piers produced no appreciable effect on the distribution of flow at the end sill (compare top plot of plate 21 with center plot of plate 19) or erosion of the exit area (compare plate 25 with plate 20).

29. A series of tests was conducted with the distance from the beginning of the stilling basin to the front face of the first row of baffle piers varied from 69 ft to 128 ft. Results indicated that the velocity distribution at the end sill was not appreciably changed by movement of the baffle piers as far downstream as 110 ft from the beginning of the basin. However, when the baffle piers were placed 128 ft from the beginning of the basin their effectiveness was reduced (plate 26).

Elevation of basin

30. End sill velocity versus tailwater curves (plate 18) indicated that the floor of the original stilling basin was near the optimum elevation. (Economy dictated that the basin be placed at as high an elevation as practicable.) However, to verify this a test was conducted with the stilling basin floor raised 5 ft to el 1128 (type 3 stilling basin). Velocities over the end sill and scour downstream

were greater with the type 3 basin installed than with the original stilling basin (compare top and center plots of plates 27 and 19, respectively, and plates 28 and 20).

Length of basin

31. The length of the stilling basin apron was reduced successively from 220 ft (type 1-B) to 205 ft (type 2-B) to 180 ft (type 5). For this series of tests the baffle piers were maintained at their original locations and a 9-ft-high end sill was used. Scour tests revealed negligible differences in erosion tendencies of the three basins (compare plates 24, 29, and 30). Also, velocities over the end sill of the shortest basin (bottom plot, plate 27) were only slightly higher than those over the end sill of the longest basin (center plot, plate 21). Bottom velocities over the end sill for the complete range of tailwater elevations actually were slightly more favorable in the shortest basin (plate 31) than they were in the longest basin (plate 23).

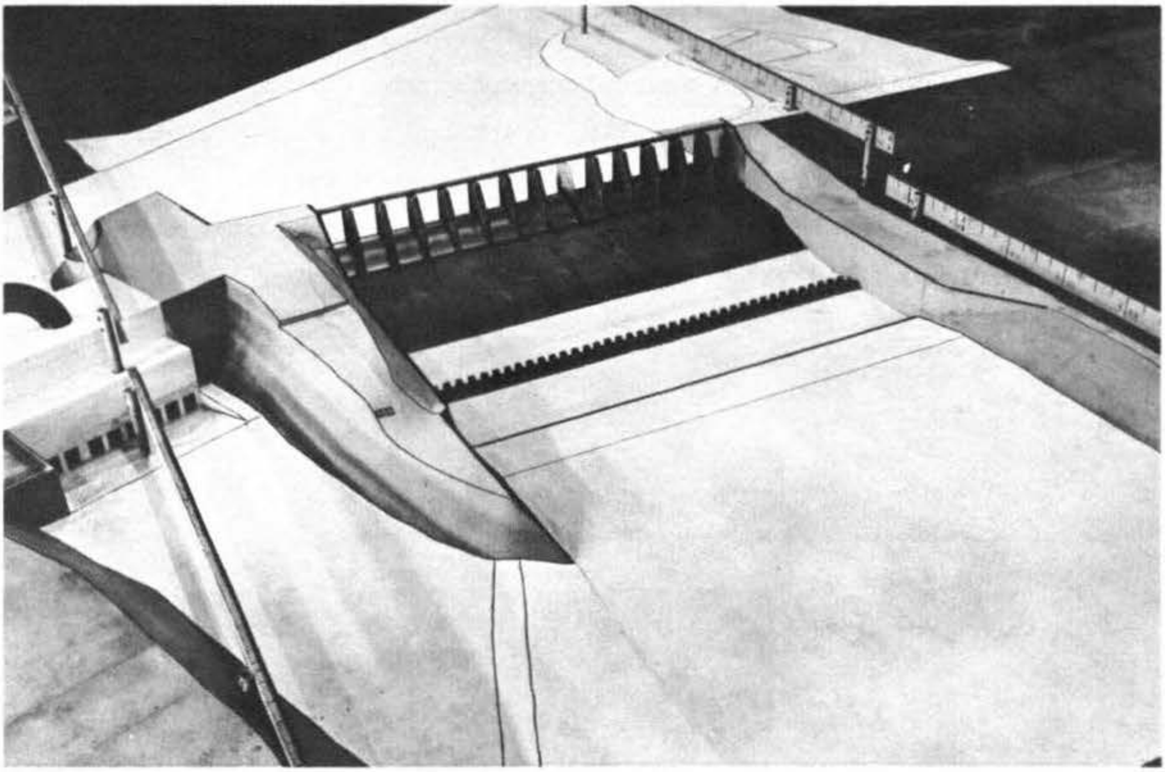
Adopted design

32. Following the tests discussed in the preceding paragraphs, design engineers of the Omaha District and the Missouri River Division met at the Waterways Experiment Station and decided to adopt the type 1-B stilling basin. This basin was comprised of a 220-ft-long apron at el 1123. Installed on the apron were two rows of 8-ft-high baffle piers located 69 and 87 ft downstream from the beginning of the basin, and a 9-ft-high end sill. The only difference between the original design and type 1-B stilling basin was that the end sill was reduced in height from 14 ft to 9 ft. Views of the model with the type 1-B stilling basin installed are presented on fig. 9. Results of tests made to compare this basin with the original design were discussed in paragraph 27. Figs. 10, 11, 12, and 13 illustrate flow conditions for various discharges and tailwaters. Water-surface elevations in the lower portion of the chute, stilling basin, and exit channel are given in tables 7, 8, and 9.

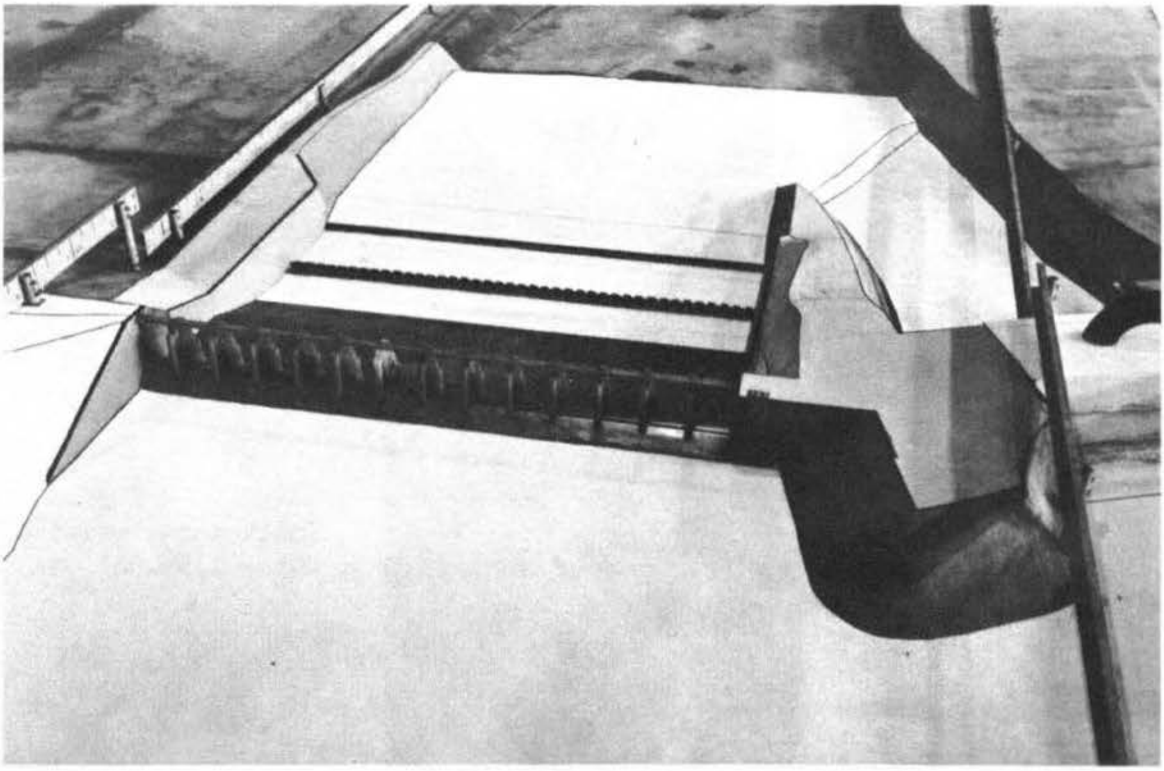
Powerhouse Tailrace

33. The powerhouse tailrace will be excavated to el 1134 and will

enter the spillway discharge channel from the right side a short distance downstream from the spillway stilling basin (plate 1). Observations were made in the model to determine whether eddy action is likely to develop in the tailrace. Tests revealed excellent alignment of currents in the tailrace and no undesirable eddy action under any conditions (fig. 14).

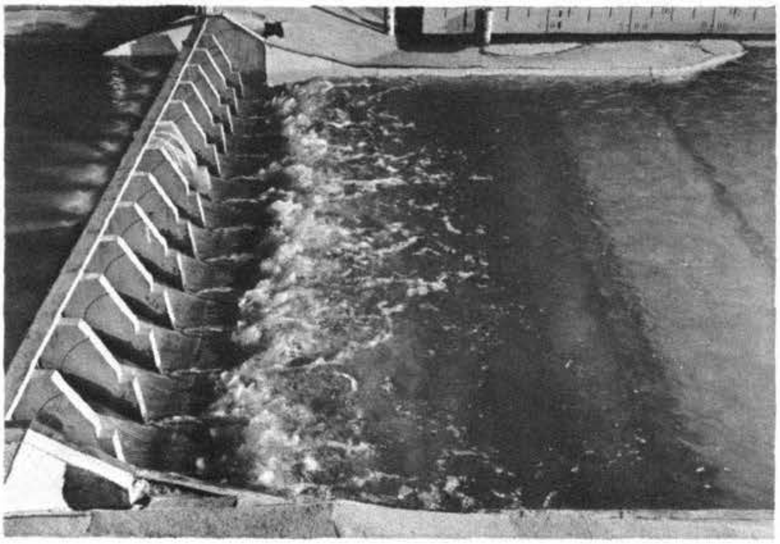


Upstream view



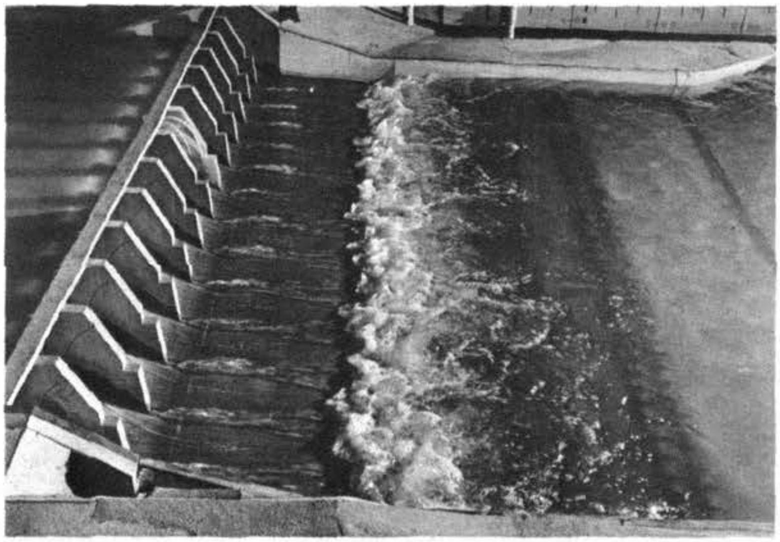
Downstream view

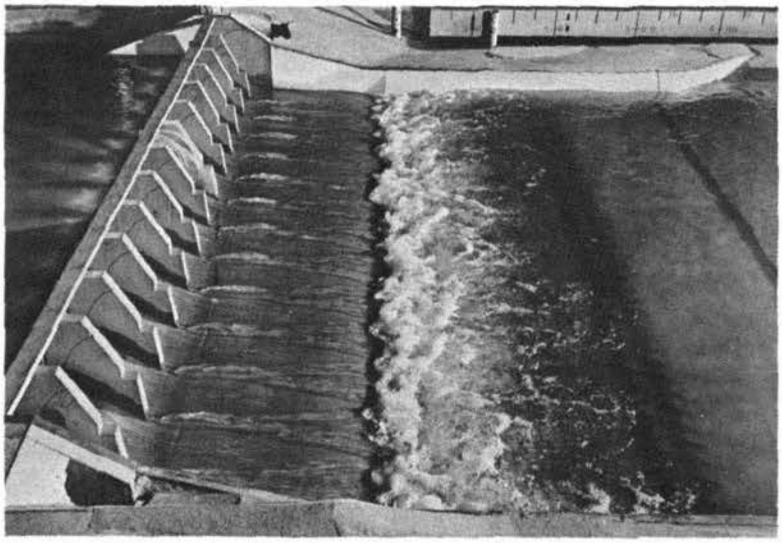
Fig. 9. Adopted design



Tailwater elevation, 1172.6

Tailwater elevation, 1165.6

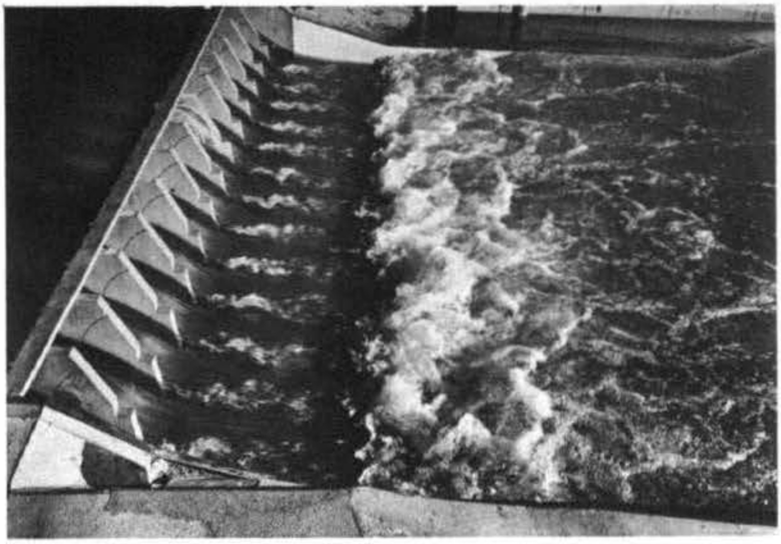




Tailwater elevation, 1159.8

Fig. 10. Stilling action, adopted design. Discharge, 100,000 cfs

Tailwater elevation,
1180.6



Tailwater elevation,
1175.4

Tailwater elevation,
1170.2

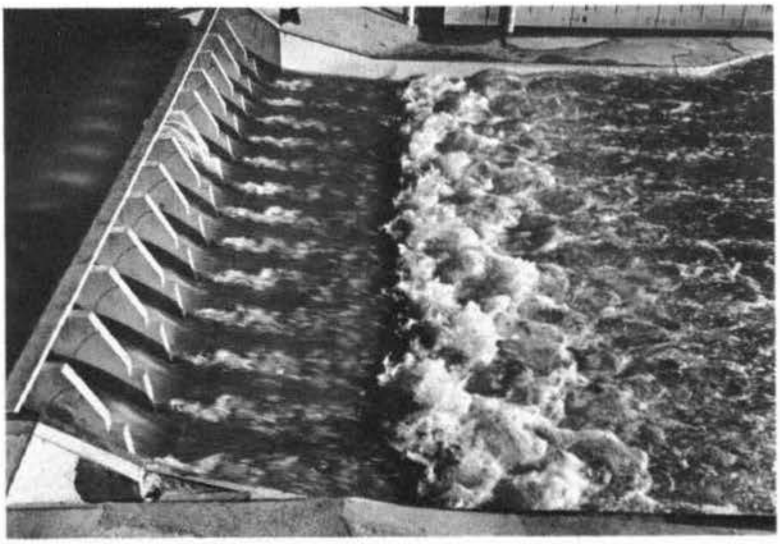
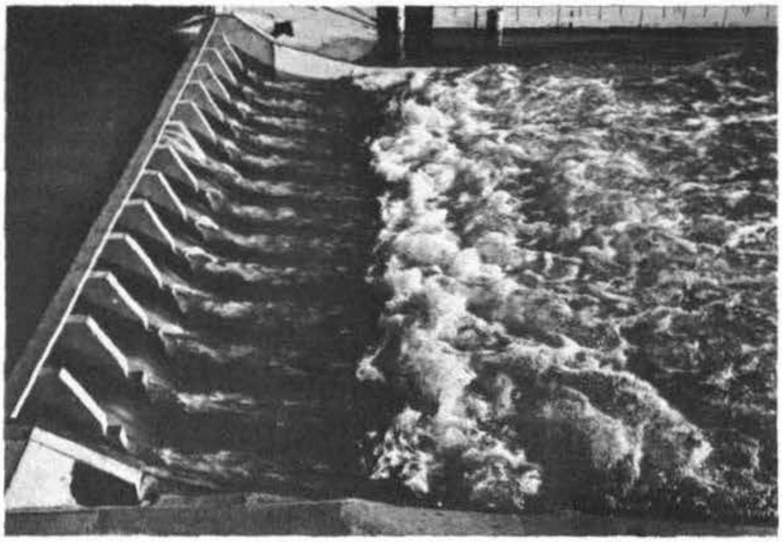
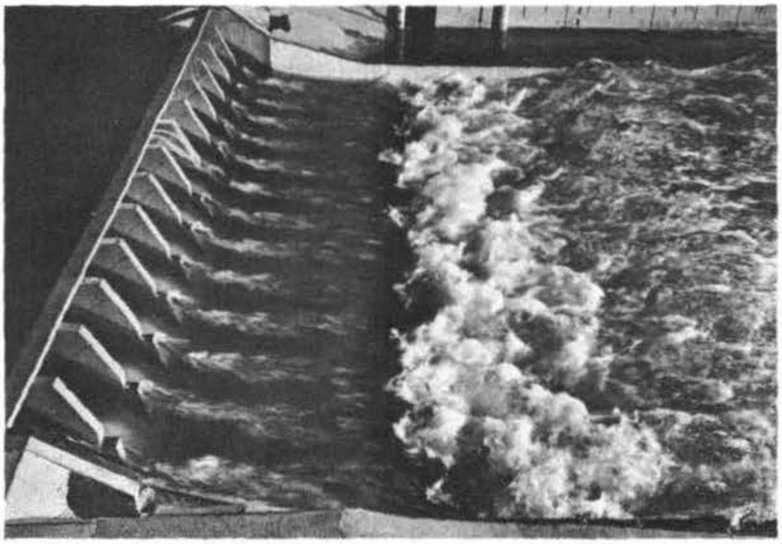


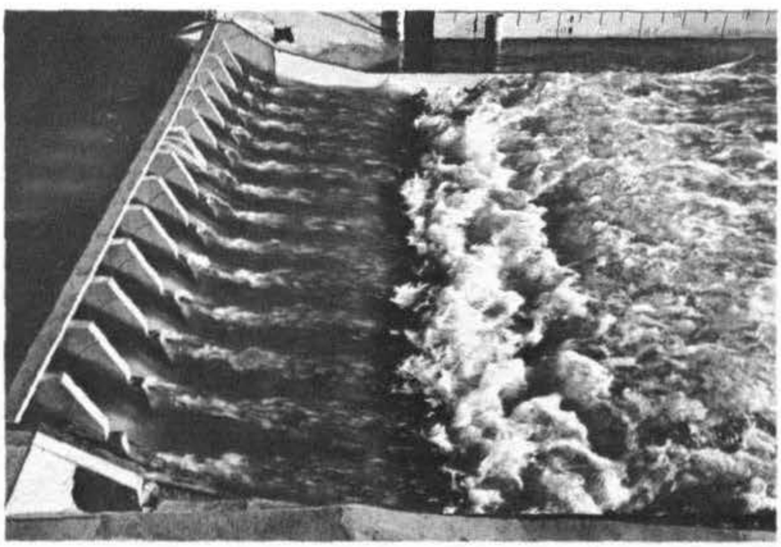
Fig. 11. Stilling action, adopted design. Discharge, 364,000 cfs



Tailwater elevation, 1185.0



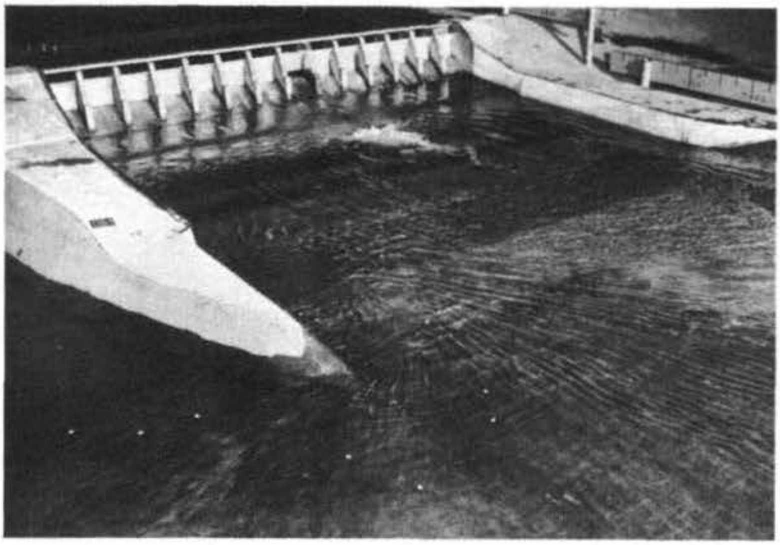
Tailwater elevation, 1180.7

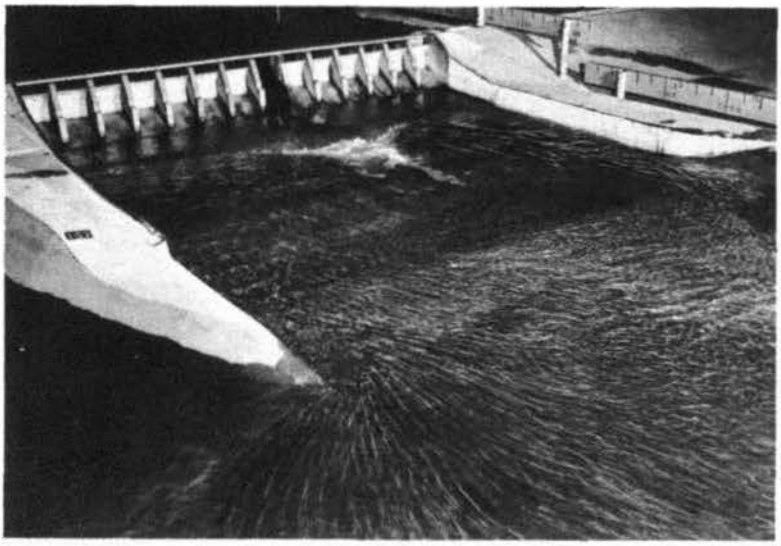


Tailwater elevation, 1176.3

Fig. 12. Stilling action, adopted design. Discharge, 626,000 cfs

Gate 8, open 10 ft
Discharge, 11,350 cfs
Tailwater el, 1149.5





Gate 8, open full
Discharge, 23,500 cfs
Tailwater el, 1152.3

Gates 7, 8, and 9,
open full
Discharge, 72,400 cfs
Tailwater el, 1157.8

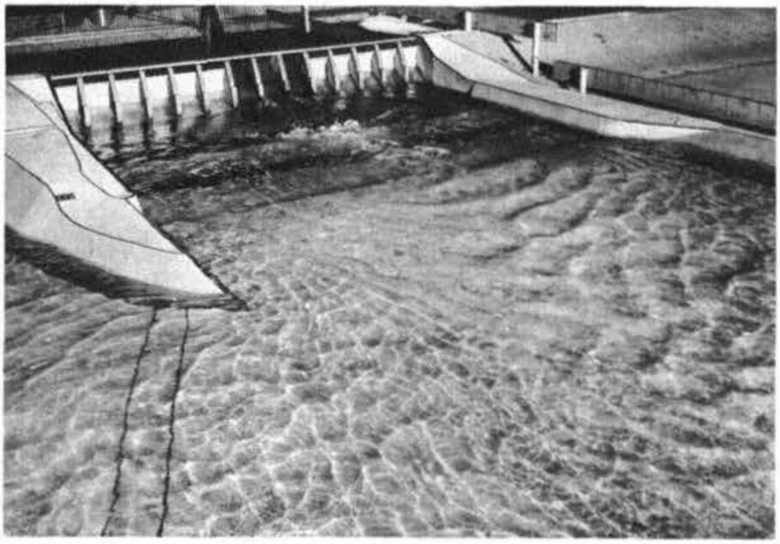
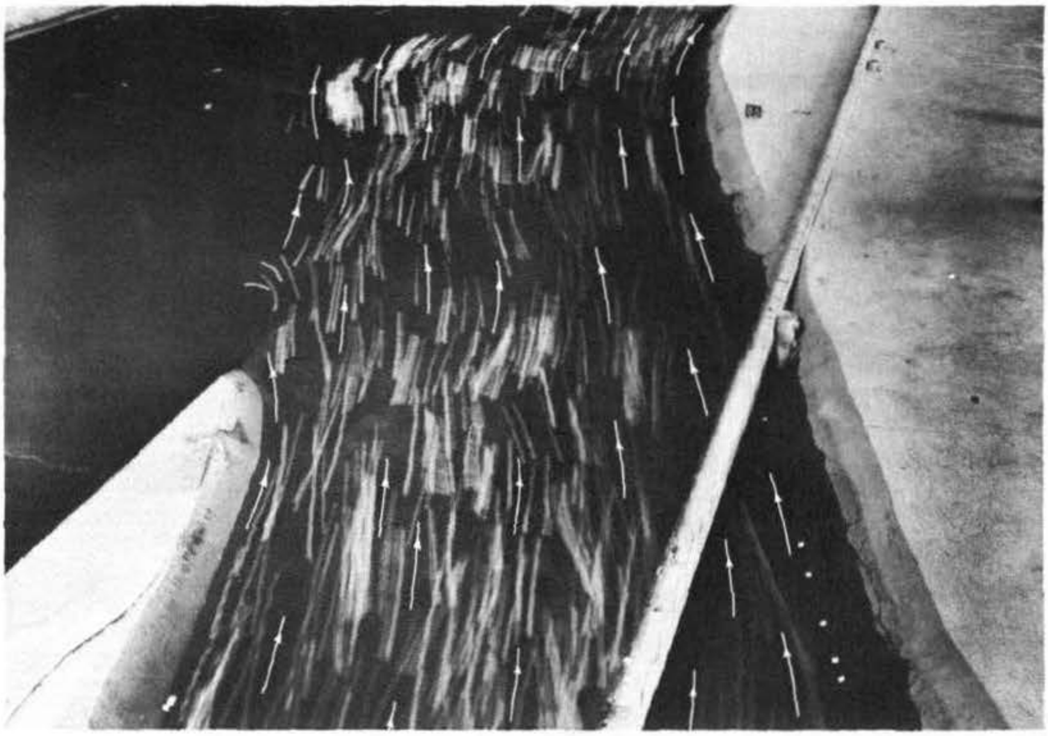
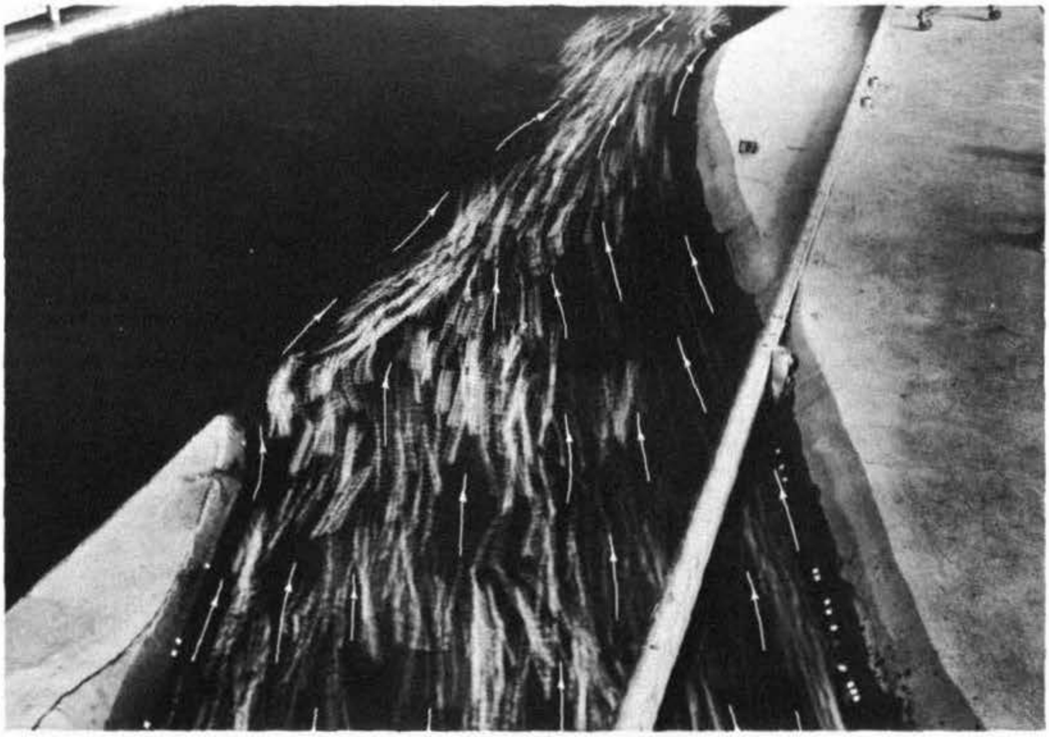


Fig. 13. Stilling action, adopted design. Pool elevation, 1210.0

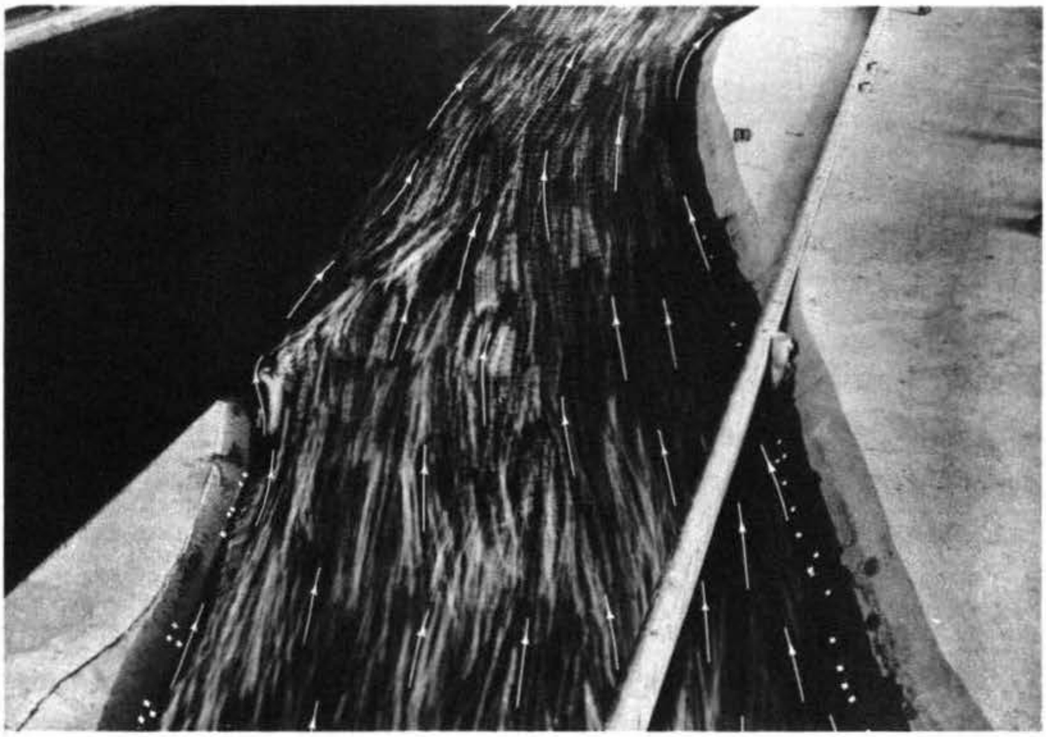


Discharge: spillway, 0 cfs; tailrace, 15,000 cfs
Tailwater elevation, 1159.9



Discharge: spillway, 100,000 cfs; tailrace, 15,000 cfs
Tailwater elevation, 1167.1

Fig. 14a. Flow in powerhouse tailrace



Discharge: spillway, 100,000 cfs; tailrace, 27,000 cfs
Tailwater elevation, 1167.7

Discharge: spillway, 364,000 cfs; tailrace, 27,000 cfs
Tailwater elevation, 1176.0

Fig. 14b. Flow in powerhouse tailrace

PART IV: DISCUSSION OF RESULTS

34. Model tests revealed the need for a dike upstream from the left abutment of the spillway to prevent lateral flow along the face of the embankment and to improve flow conditions in the left side of the spillway. Alignment of the dike recommended for installation in the prototype is shown on plate 4. In developing this alignment, efforts first were made to cause flow to cling to the bank and move smoothly around the dike and into the left bay of the spillway. However, it was found that the sloping (1 on 2) sides of the dike caused the formation of eddies which moved out into the flow and resulted in turbulent conditions in the left side of the spillway. With the dike as recommended, a fixed eddy formed between the dike and the spillway; but immediately downstream from this eddy flow moved smoothly into the left bay of the spillway. Installation of the dike resulted in a 2.8 per cent increase in the capacity of the spillway at the maximum flood pool.

35. Flow conditions over the weir and around the crest piers were found to be satisfactory. The weir discharge coefficient of 3.95 obtained at the design head was as high as could be expected for the relatively low weir and high approach velocities. Also the pier contraction coefficient, 0.006, obtained at the design head was a reasonable value. There was an area of negative pressure along the intersection of the weir and pier immediately downstream from the bulkhead slot in the pier, but cavitation in this zone is unlikely since the minimum pressure was only -9 ft.

36. Performance of the stilling basin of original design was satisfactory. However, distribution of flow leaving the basin was improved by reducing the height of the end sill from 14 ft to 9 ft. Tests confirmed the necessity for baffle piers on the stilling basin apron and demonstrated that an increase in the elevation of the apron, which was selected to give only 86 per cent of D_2 at the design flood, was undesirable. Model data revealed that end sill velocities would not be changed appreciably by a reduction in length of the spillway apron from 220 ft ($3.6D_2$) to 180 ft ($3D_2$). However, it was decided

that because of the relatively high average velocity (about 20 ft per sec) in the exit channel, the 220-ft-long apron was warranted in order to reduce turbulence in the exit channel to a minimum.

Table 1

Velocity Distribution in Approach Channel

Station 1+25 Upstream of Weir Crest

Discharge 580,000 cfs; Pool Elevation 1221.34

Distance in ft from Center Line of Spillway		Velocity Direction	Velocity in ft per sec										
			Distance in ft above Approach Channel Elevation 1155.0										
Left	Right	Degrees	2	4	6	8	10	20	30	40	50	60	62.5
315		0	6.2	6.2	6.2	8.8	10.4	10.4	8.8	6.2	6.2	6.2	6.2
300		0	10.4	12.4	13.2	13.9	13.9	12.4	10.4	10.4	10.4	10.4	8.8
250		0	13.9	13.9	16.4	16.4	16.4	16.4	17.6	16.4	17.6	16.4	16.4
200		0	13.2	13.9	13.9	15.2	15.2	15.2	15.2	15.2	15.2	15.2	16.4
150		0	12.4	13.9	15.2	15.2	15.2	15.8	15.2	15.2	15.2	14.6	13.9
100		0	11.6	13.9	14.6	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9
50		0	10.4	12.4	13.2	13.9	13.9	14.6	13.9	13.9	13.9	13.9	13.9
℄		0	10.4	11.6	12.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
	50	0	10.4	12.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
	100	0	10.4	11.6	11.6	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
	150	0	10.4	12.4	12.4	12.4	12.4	12.4	13.2	12.4	13.2	13.2	13.2
	200	345	10.4	11.6	12.4	12.4	12.4	12.4	12.4	12.4	12.4	13.2	13.2
	250	345	10.4	11.6	11.6	12.4	12.4	12.4	11.6	10.8	10.8	10.8	10.8
	300	340	8.8	9.8	10.8	10.8	10.8	10.8	10.8	10.8	9.8	10.8	10.8
	325	330	7.6	----	----	----	----	----	----	----	----	----	----
	350	330	7.6	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
	400	330	7.6	6.2	7.6	8.8	8.8	8.8	8.8	8.8	8.8	8.8	7.6
	415	340	6.2	6.2	----	----	----	----	----	----	----	----	----
	420	340	----	----	7.6	----	----	----	----	----	----	----	----
	470	350	----	----	----	----	----	----	----	----	----	6.2	----

Note: Angle of flow measured clockwise from downstream direction.

Table 2

Pressures on Spillway Weir and Crest Piers

Full Gate Opening

		Pressures												
Piez No.	Piez Zero	Discharge 50,000 cfs Pool El 1189.0	Discharge 100,000 cfs Pool El 1193.7	Discharge 150,000 cfs Pool El 1197.8	Discharge 200,000 cfs Pool El 1201.3	Discharge 250,000 cfs Pool El 1204.6	Discharge 300,000 cfs Pool El 1207.5	Discharge 330,000 cfs Pool El 1209.1	Discharge 400,000 cfs Pool El 1212.8	Discharge 450,000 cfs Pool El 1215.3	Discharge 500,000 cfs Pool El 1217.8	Discharge 550,000 cfs Pool El 1219.9	Discharge 577,000 cfs Pool El 1221.2	Discharge 613,800 cfs Pool El 1222.9
1	1173.7	15.1	19.3	22.7	26.1	28.2	30.8	32.1	35.1	36.5	38.5	40.3	40.8	42.2
2	1176.3	12.0	15.7	19.0	21.7	23.7	25.7	26.5	28.7	29.7	31.0	32.2	32.7	33.5
3	1178.0	9.4	12.0	13.8	15.0	15.6	16.0	16.4	16.4	16.5	16.0	16.0	15.5	16.0
4	1178.6	8.4	10.9	12.6	13.3	13.9	13.7	13.8	13.4	13.4	12.9	12.9	11.6	12.4
5	1179.3	6.7	8.7	9.7	10.6	10.7	10.7	10.5	9.7	8.7	7.9	7.1	6.7	6.7
6	1179.8	6.1	8.1	9.0	10.0	10.2	10.2	10.0	9.6	9.2	8.2	7.7	7.2	7.2
7	1180.0	5.1	7.0	7.8	8.3	8.7	8.5	8.2	7.9	7.0	6.5	6.3	5.7	5.5
8	1179.8	4.8	6.2	7.4	8.0	8.1	8.2	7.9	8.0	8.0	7.0	6.6	6.2	6.2
9	1179.2	4.6	5.8	7.0	7.5	7.8	7.8	7.8	7.8	7.4	6.9	7.0	6.6	6.8
10	1177.8	3.7	5.0	5.7	6.2	6.7	7.2	7.2	7.4	7.7	8.0	8.0	9.9	8.2
11	1175.3	2.6	3.7	4.7	5.2	5.7	6.2	6.7	7.4	8.2	8.3	8.8	8.7	10.2
12	1171.9	1.9	3.1	3.8	4.9	5.9	6.6	7.9	9.1	10.1	11.3	12.6	12.6	14.1
13	1167.4	2.7	4.6	7.0	9.4	11.4	13.4	14.6	17.6	19.6	21.1	22.9	23.6	25.6
14	1162.7	4.3	7.8	11.3	14.8	17.7	16.1	17.8	26.3	28.3	30.3	32.3	33.3	30.8
15	1159.2	4.2	7.8	12.0	15.8	19.5	22.8	24.8	29.8	32.4	34.3	36.6	37.8	40.6
16	1173.7	15.1	19.3	22.9	26.3	28.5	31.0	32.3	35.3	37.0	38.7	40.6	40.8	42.3
17	1176.3	12.4	16.0	19.3	21.7	23.7	25.7	26.7	28.7	30.1	30.7	32.0	31.9	33.5
18	1178.0	9.4	11.9	13.5	15.0	15.9	16.0	16.2	16.4	16.0	15.1	15.4	14.0	14.0
19	1178.6	8.2	10.4	12.2	13.3	14.2	14.1	14.2	14.4	14.4	13.3	13.4	12.4	12.4
20	1179.3	6.7	8.7	9.7	10.6	10.8	10.6	10.5	10.0	9.9	8.5	8.7	6.7	8.2
21	1179.8	6.0	7.5	8.0	8.2	8.0	7.4	7.0	5.5	4.8	2.5	3.2	1.2	3.2
22	1180.0	5.0	6.4	7.0	7.0	6.7	6.0	5.5	4.6	3.5	1.5	1.3	-0.2	1.0
23	1179.8	4.6	6.2	6.4	6.8	7.0	6.3	6.8	5.2	4.8	3.9	4.2	2.5	3.2
24	1179.2	4.7	5.8	6.8	7.3	7.7	7.3	7.1	7.2	7.2	6.7	6.9	6.3	6.3
25	1177.8	4.0	5.2	6.0	6.7	7.2	7.9	8.0	8.5	9.2	8.6	9.2	9.0	9.2
26	1175.3	2.7	4.2	4.9	5.7	6.5	7.2	7.7	9.4	10.0	9.6	10.2	10.2	11.7
27	1171.9	2.5	3.1	4.9	6.1	7.1	8.1	8.3	9.3	10.1	12.1	13.1	13.1	15.1
28	1167.4	2.8	5.2	7.2	8.6	9.9	11.6	12.6	15.9	17.6	19.6	21.0	22.6	23.6
29	1162.7	5.1	8.5	11.3	13.9	16.7	14.6	16.2	24.3	26.6	28.3	30.1	31.3	28.8
30	1159.2	4.0	6.6	8.8	11.6	14.2	14.8	18.8	20.6	26.0	27.6	30.6	31.1	34.8
31	1178.5	8.8	11.5	14.2	15.8	17.2	18.2	18.5	19.5	20.4	19.8	20.0	29.7	20.5
32	1180.0	6.0	7.5	7.0	5.7	4.2	1.5	0.0	-1.5	-3.5	-6.6	-5.5	-9.0	-7.5
33	1180.5	4.7	6.5	7.3	7.8	8.0	7.5	7.3	7.0	6.5	5.5	5.3	4.4	5.5
34	1180.0	5.0	6.3	7.8	8.5	9.0	9.0	9.2	9.5	9.0	9.0	7.0	8.0	7.0
35	1183.0	4.3	7.5	9.8	11.3	12.4	13.0	13.4	14.3	14.4	13.7	14.0	13.5	14.5
36	1183.0	4.0	6.5	8.3	9.2	10.5	11.0	11.0	11.7	11.9	11.0	11.0	10.8	11.0
37	1183.0	3.5	5.7	7.0	8.2	9.0	9.3	9.3	10.0	10.0	9.8	10.0	9.1	9.0
38	1183.0	2.0	4.4	5.5	6.7	7.4	8.0	8.0	8.8	9.0	9.0	9.0	6.8	8.5
39	1186.0	*	4.0	6.5	8.2	9.7	11.0	11.2	12.2	13.0	13.5	14.0	13.8	14.0
40	1186.0	*	3.3	5.2	6.7	7.5	9.0	9.6	10.5	11.0	11.5	12.0	11.8	12.0
41	1192.0	*	*	*	3.9	6.0	8.0	8.5	10.1	11.0	11.5	12.3	12.5	13.5
42	1192.0	*	*	*	2.6	4.5	6.0	7.0	8.8	10.0	10.3	11.5	11.3	12.0
43	1198.0	*	*	*	*	*	3.0	4.2	6.1	8.0	8.8	9.5	10.0	11.0
44	1198.0	*	*	*	*	*	*	2.5	5.2	6.5	7.7	8.5	9.0	10.0
45	1204.0	*	*	*	*	*	*	*	*	3.5	4.3	5.5	6.0	7.0
46	1204.0	*	*	*	*	*	*	*	*	2.2	4.0	5.3	5.8	7.0
47	1210.0	*	*	*	*	*	*	*	*	*	*	2.5	3.0	4.0
48	1210.0	*	*	*	*	*	*	*	*	*	*	*	*	3.0

Note: Pressures are recorded in prototype feet of water.
Locations of piezometers shown on plate 12.
*Denotes piezometer opening free of water.

Table 3

Pressures on Spillway Weir and Crest Piers

Partial Gate Opening, Pool Elevation 1210.0

Piez No.	Piez Zero	Spillway Gate No. 7 Operating — Pressures: Gate Open 5 ft Discharge 6,200 cfs	Gate Open 10 ft Discharge 11,350 cfs	Gate Open 15 ft Discharge 15,900 cfs	Gate Open 20 ft Discharge 21,300 cfs	Spillway Gates Nos. 6, 7, and 8 Operating — Pressures: Gates Open 5 ft Discharge 16,750 cfs	Gates Open 10 ft Discharge 32,000 cfs	Gates Open 15 ft Discharge 45,300 cfs	Gates Open 20 ft Discharge 61,400 cfs
1	1173.7	36.8	36.1	35.3	34.6	36.6	36.1	35.3	34.1
2	1176.3	34.2	33.1	31.7	30.2	34.1	33.3	31.5	29.6
3	1178.0	31.7	28.8	26.0	20.3	31.7	28.8	25.8	21.6
4	1178.6	31.0	27.4	23.9	20.2	30.9	27.4	23.7	19.4
5	1179.3	29.5	24.7	20.7	16.5	29.4	25.0	20.9	15.8
6	1179.8	28.2	23.2	19.2	15.2	28.3	23.5	19.5	15.1
7	1180.0	27.0	20.5	16.3	13.2	27.0	21.0	17.0	13.2
8	1179.8	24.0	16.9	14.0	12.0	24.0	17.4	14.6	12.2
9	1179.2	17.2	12.6	11.2	10.6	17.2	12.8	11.8	10.8
10	1177.8	1.6	3.7	5.7	7.0	1.5	3.7	5.7	7.2
11	1175.3	0.3	0.7	2.7	4.7	0.5	1.0	2.6	5.4
12	1171.9	0.1	0.4	2.3	4.6	0.1	0.3	2.0	5.0
13	1167.4	3.1	6.1	8.8	11.8	3.1	6.0	8.6	12.1
14	1162.7	6.6	12.0	16.3	19.5	6.5	11.5	15.7	20.1
15	1159.2	6.3	12.6	17.3	21.0	6.3	12.0	16.8	22.0
16	1173.7	36.3	36.1	35.3	34.5	36.5	36.0	35.1	34.0
17	1176.3	34.0	33.3	32.1	31.0	34.2	33.3	31.5	29.4
18	1178.0	31.9	29.9	27.0	21.8	31.8	29.0	25.8	21.2
19	1178.6	31.2	28.7	25.4	21.8	31.1	27.9	24.4	19.6
20	1179.3	29.9	26.2	22.5	18.5	29.2	25.0	21.0	16.0
21	1179.8	28.9	24.1	20.2	15.2	28.4	22.2	17.0	12.0
22	1180.0	27.0	21.0	17.0	14.8	27.0	20.0	15.5	10.7
23	1179.8	24.4	18.2	15.2	12.2	22.7	17.0	14.4	11.4
24	1179.2	19.8	15.6	13.8	13.8	18.2	14.0	13.4	12.0
25	1177.8	3.0	6.0	8.2	9.7	3.2	5.0	7.0	8.5
26	1175.3	1.2	2.7	4.7	7.7	-0.3	0.7	3.0	6.0
27	1171.9	2.1	2.9	4.4	6.9	1.9	2.1	3.8	6.3
28	1167.4		5.3	8.9	12.6	3.1	5.6	8.5	11.8
29	1162.7	7.1	11.9	16.1	19.3	7.3	11.8	15.5	18.6
30	1159.2	5.8	8.8	11.3	14.8	5.8	9.1	12.0	15.7
31	1178.5	30.8*	28.3*	25.5*	23.0*	31.0	29.3	26.5	23.9
32	1180.0	29.3*	25.7*	20.8*	17.0*	29.2	25.0	19.5	13.4
33	1180.5	26.5*	21.3*	17.9*	14.7*	26.3	20.7	17.3	13.9
34	1180.0	22.4*	18.0*	16.0*	14.5*	22.0	17.2	15.5	13.6
35	1183.0	26.8	24.3	21.8	18.8	26.8	24.5	21.7	17.8
36	1183.0	26.3	22.3	18.5	15.6	26.7	23.0	19.8	15.8
37	1183.0	25.0	20.2	17.0	14.5	25.0	20.2	17.2	14.0
38	1183.0	20.3	13.0	12.9	11.8	21.0	14.9	13.5	12.0
39	1186.0	23.8	21.0	18.5	15.3	24.0	21.2	18.8	15.9
40	1186.0	22.4	17.5	15.0	13.0	23.0	19.0	16.0	13.7
41	1192.0	17.9	15.5	13.8	12.0	18.2	17.2	15.2	12.7
42	1192.0	17.9	15.5	10.0	10.0	18.2	16.8	12.8	11.4
43	1198.0	12.2	10.3	8.3	8.0	12.4	12.2	10.4	9.2
44	1198.0	12.4	11.5	10.4	6.0	12.3	12.0	10.6	8.4
45	1204.0	6.4	4.8	2.8	2.8	6.3	6.1	4.8	3.8
46	1204.0	6.6	6.0	5.0	2.9	6.4	6.3	5.9	3.8
47	1210.0	Piezometers free of water							
48	1210.0								

Note: Pressures are recorded in prototype feet of water.
Locations of piezometers shown on plate 12.
Spillway bays are numbered from right to left.
*Data procured with spillway gate No. 6 in operation.

Table 4

Water-surface Elevations -- Approach Channel, Weir, and Chute

Discharge, 100,000 cfs; Pool Elevation, 1193.7

	Bay No. 1				Bay No. 8			Bay No. 14			
Sta	2.5 ft from Training Wall	10 ft from Training Wall	Center Line	2.5 ft Rt of Pier No. 1	2.5 ft Left of Pier No. 7	Center Line	2.5 ft Rt of Pier No. 8	2.5 ft Left of Pier No. 13	Center Line	10 ft from Training Wall	2.5 ft from Training Wall
-3+00		1193.20				1193.50				1193.32	
-2+50		1193.14				1193.44				1193.08	
-2+00		1193.14				1193.44				1193.56	
-1+50		1193.14				1193.26				1193.50	
-1+00		1193.02				1193.32				1193.08	
-0+50	1193.08	1192.90	1192.90	1193.02	1193.08	1193.08	1193.14	1192.96	1192.90	1192.90	1193.08
-0+25	1192.06	1192.48	1192.60	1192.66	1192.96	1192.84	1192.90	1192.72	1192.66	1192.66	1192.60
-0+20	1191.40	1191.82	1192.42	1192.60	1192.72	1192.66	1192.66	1192.60	1192.54	1192.54	1192.48
-0+15	1191.10	1191.46	1192.00	1192.48	1192.48	1192.48	1192.90	1192.24	1192.18	1192.18	1192.00
-0+10	1190.62	1191.04	1191.46	1191.40	1191.16	1191.76	1191.64	1190.68	1191.76	1191.76	1191.40
-0+05	1190.38	1190.20	1190.56	1190.02	1189.06	1190.92	1189.66	1189.18	1190.74	1190.74	1190.74
0+00	Crest axis										
0+10	1185.16	1185.22	1185.16	1185.40	1185.40	1185.64	1185.46	1185.22	1185.28	1185.64	1185.34
0+20	1179.04	1179.76	1179.58	1179.34	1179.34	1179.40	1179.34	1179.22	1179.28	1179.70	1179.04
0+30	1172.30	1172.50	1172.62	1172.32	1171.30	1172.08	1171.36	1172.08	1172.44	1172.80	1172.02
0+40	1165.00	1165.30	1165.42	1165.42	1165.90	1164.88	1165.66	1165.66	1165.24	1165.96	1165.30
0+50	1161.10	1161.28	1161.40	1161.28	1161.28	1160.98	1161.28	1161.28	1161.58	1161.10	1161.10
0+75		1158.28				1159.12				1157.92	
1+00		1157.20				1158.10				1157.62	
1+25		1156.60				1156.18				1156.48	
1+50		1155.34				1154.62				1155.22	

Note: Stations refer to downstream distance in feet from weir crest.
Spillway bays and piers are numbered from right to left.

Table 5

Water-surface Elevations -- Approach Channel, Weir, and Chute

Discharge, 364,000 cfs; Pool Elevation, 1211.0

	Bay No. 1				Bay No. 8			Bay No. 14			
Sta	2.5 ft from Training Wall	10 ft from Training Wall	Center Line	2.5 ft Rt of Pier No. 1	2.5 ft Left of Pier No. 7	Center Line	2.5 ft Rt of Pier No. 8	2.5 ft Left of Pier No. 13	Center Line	10 ft from Training Wall	2.5 ft from Training Wall
-3+00	1210.00					1210.00					1208.62
-2+50	1210.00					1210.00					1207.96
-1+50	1209.88					1209.40					1208.86
-1+00	1209.76					1209.40					1209.28
-0+50	1209.34	1208.98	1208.80	1208.86	1208.86	1209.10	1209.10	1208.38	1208.50	1208.80	1208.56
-0+25	1205.44	1205.92	1207.12	1208.08	1208.38	1208.02	1208.32	1207.78	1207.42	1207.66	1207.36
-0+20	1202.80	1204.18	1206.46	1207.84	1208.26	1207.72	1208.20	1207.60	1206.88	1207.00	1206.88
-0+15	1200.28	1202.92	1205.32	1208.80	1209.04	1207.18	1208.92	1207.48	1206.10	1206.64	1206.28
-0+10	1197.52	1201.78	1204.12	1207.12	1206.70	1206.40	1207.00	1205.98	1205.08	1205.56	1205.56
-0+05	1196.98	1199.44	1203.16	1205.38	1203.16	1205.38	1206.52	1202.02	1204.12	1204.60	1204.12
0+00	Crest axis										
0+10	1193.32	1194.28	1197.88	1197.40	1195.90	1199.38	1196.32	1193.68	1197.76	1199.26	1198.78
0+20	1190.20	1190.20	1192.00	1191.88	1190.80	1193.02	1191.82	1189.30	1191.40	1193.68	1192.78
0+30	1185.52	1184.26	1185.10	1184.98	1186.00	1186.00	1186.36	1183.90	1186.30	1187.62	1186.72
0+40	1175.92	1177.60	1175.98	1176.40	1178.38	1176.76	1178.50	1176.40	1177.90	1180.00	1179.88
0+50	1174.18	1173.10	1170.52	1169.98	1172.68	1171.12	1172.32	1170.58	1171.36	1173.82	1173.40
0+75		1166.98				1165.84				1166.32	
1+00		1164.04				1164.40				1163.80	
1+25		1162.66				1162.78				1162.24	
1+50		1161.58				1162.18				1160.44	

Note: Stations refer to downstream distance in feet from weir crest.
Spillway bays and piers are numbered from right to left.

Table 6

Water-surface Elevations -- Approach Channel, Weir, and Chute

Discharge, 626,000 cfs; Pool Elevation, 1223.5

	Bay No. 1				Bay No. 8			Bay No. 14			
Station	2.5 ft from Training Wall	10 ft from Training Wall	Center Line	2.5 ft Rt of Pier No. 1	2.5 ft Left of Pier No. 7	Center Line	2.5 ft Rt of Pier No. 8	2.5 ft Left of Pier No. 7	Center Line	10 ft from Training Wall	2.5 ft from Training Wall
-3+00		1221.6				1221.6				1219.6 1216.6	
-2+50		1221.6				1221.3				1219.3 1216.6	
-2+00		1221.3				1221.0				1218.7 1217.2	
-1+50		1221.2				1220.7				1219.0 1217.5	
-1+00		1221.0				1220.3				1219.3 1217.8	
-0+50	1219.9	1219.6	1219.3	1219.3	1219.3	1219.3	1219.3	1218.7 1217.5	1219.0 1216.3	1219.0 1216.9	1218.4 1216.6
-0+25	1215.7 1215.1	1215.7 1213.9	1217.2 1214.8	1217.4	1218.6	1218.3	1218.5	1217.2	1217.0	1217.8 1216.0	1218.0 1215.7
-0+20	1213.3 1212.7	1214.2 1212.1	1215.4 1213.9	1217.2	1218.3	1217.8	1218.3	1216.6	1216.3	1216.6 1215.1	1217.2 1214.8
-0+15	1209.9 1208.7	1210.9 1210.1	1214.2 1213.2	1217.0	1219.5	1217.1	1218.9	1218.0	1214.2	1216.0 1213.6	1215.4 1213.3
-0+10	1204.6 1203.7	1206.9 1205.8	1211.8 1210.0	1218.0	1218.9	1216.2	1219.3	1217.2 1214.8	1215.1 1212.7	1214.8 1212.7	1215.0 1212.9
-0+05	1203.4 1202.4	1205.8 1203.7	1210.3 1208.8	1216.4	1214.5	1215.0	1215.6	1214.7 1209.6	1214.5 1211.9	1214.5 1211.2	1214.5 1211.8
0+00	Crest axis										
0+10	1197.7	1199.3	1205.2	1209.5	1206.5	1210.2	1209.3	1204.5	1207.3	1208.4	1208.4
0+20	1194.2	1195.3	1201.4	1202.8	1200.6	1205.6	1203.0	1196.5	1200.4	1203.6 1201.6	1203.7 1202.2
0+30	1189.1	1189.8	1195.8	1194.2	1195.0	1197.3	1195.5	1191.1	1193.6	1197.7 1194.4	1197.9 1195.9
0+40	1184.1		1188.2	1186.4	1189.0	1189.0	1189.4	1184.0	1187.6	1191.0 1187.5	1190.9 1188.1
0+50	1181.2	1181.0	1181.9	1178.9	1184.0	1182.9	1184.0	1179.2	1181.5	1184.7 1180.2	1185.6 1184.9
0+75		1172.8				1173.0				1173.6	
1+00		1170.7				1169.9				1169.7	
1+25		1169.9				1168.5				1167.9	
1+50		1166.9				1168.3				1166.3	

Note: Stations refer to downstream distance in feet from weir crest.
Spillway bays and piers are numbered from right to left.
Two readings on same station denote pulsating wave.

Table 7

Water-surface Elevations -- Chute, Type 1-B Stilling Basin, and Exit Channel

Discharge, 100,000 cfs

	Tailwater Elevation, 1159.8			Tailwater Elevation, 1165.6			Tailwater Elevation, 1172.7		
Station	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 1 10 ft from Training Wall	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall
0+55							1160.0	1159.8	1159.8
0+65							1158.9	1158.9	1158.6
0+70							1158.5	1158.9	1158.6
0+75							1160.5	1161.0	1162.5
0+85							1162.5	1162.5	1165.5
1+00							1165.0	1166.5	1168.0
1+25							1172.5	1172.5	1172.5
1+50							1173.5	1174.0	1173.5
1+55				1153.9					
1+60				1154.2	1153.9	1154.8			
1+65				1156.0	1156.5	1156.0			
1+75	1151.68	1151.5	1152.1	1159.0	1161.0	1158.5	1174.0	1174.0	1174.0
1+85	1153.00	1154.5	1153.0						
2+00	1155.00	1155.0	1156.0	1164.0	1163.5	1162.5	1173.5	1173.0	1173.5
2+25				1165.0	1165.0	1164.5			
2+50	1159.20	1160.0	1160.0	1166.5	1166.5	1166.0	1173.5	1173.5	1173.5
2+75							1173.0	1173.0	1173.0
3+00	1160.50	1160.5	1161.0	1166.0	1166.0	1166.0			
3+25							1173.0	1173.5	1173.5
3+50	1161.00	1161.0	1161.0	1165.8	1165.8	1165.8	1173.5	1173.5	1173.5
3+75							1173.0	1173.2	1173.0
4+00	1160.50	1160.5	1160.5	1165.5	1165.8	1165.8	1173.0	1173.2	1173.0
4+50	1160.50	1160.5	1160.5	1166.5	1166.5	1166.5	1173.5	1173.5	1173.5
5+00	1160.50	1160.5	1160.5	1166.0	1166.0	1166.0	1173.5	1173.5	1173.5
5+50	1160.00	1160.0	1160.0	1165.8	1165.8	1165.8	1173.0	1173.0	1173.0
6+00	1159.80	1159.8	1159.8	1165.6	1165.6	1165.6	1172.8	1172.8	1172.8
7+00				1165.6	1165.6	1165.6	1172.8	1172.8	1172.7
8+00	1159.80	1159.8	1159.8	1165.6	1165.6	1165.6	1172.7	1172.7	1172.7

Note: Stations refer to distance in feet from weir crest.
Spillway bays and piers are numbered from right to left.

Table 8

Water-surface Elevations -- Chute, Type 1-B Stilling Basin, and Exit Channel

Discharge, 364,000 cfs

	Tailwater Elevation, 1170.2			Tailwater Elevation, 1175.4			Tailwater Elevation, 1180.6		
Station	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall
1+60							1164.0	1165.0	1164.0
1+75	1159.60	1160.74	1158.04	1161.2	1161.3	1159.8	1169.5	1169.5	1169.0
1+85	1158.40	1158.82	1157.08	1161.5	1162.5	1161.0			
2+00	1156.18	1155.40	1154.20	1162.0	1163.0	1162.0	1174.0	1175.0	1174.5
2+25	1161.00	1162.50	1161.00	1168.5	1168.5	1168.5	1175.5	1175.5	1176.0
2+50	1164.00	1165.80	1164.00	1171.0	1171.0	1171.0	1177.5	1178.0	1178.0
2+75	1165.00	1167.00	1165.50						
3+00	1167.00	1168.00	1167.00	1173.0	1172.0	1173.0	1179.8	1180.0	1179.0
3+50	1171.00	1171.00	1170.00	1176.0	1175.0	1176.0	1181.5	1180.5	1180.3
4+00	1173.50	1173.50	1173.50	1177.5	1177.0	1177.0	1181.5	1182.0	1181.5
4+50	1174.00	1174.00	1174.00	1178.0	1177.0	1176.0	1181.5	1182.0	1181.3
5+00	1173.50	1172.50	1172.50	1176.5	1176.3	1175.0	1182.0	1181.0	1181.0
5+50	1172.50	1172.00	1170.50	1175.6	1175.4	1175.4	1181.0	1181.0	1180.0
6+00	1171.30	1171.00	1171.50	1175.4	1175.4	1175.4	1180.6	1180.6	1180.6
7+00	1170.20	1170.20	1172.00						
8+00	1170.20	1170.20	1171.00	1175.4	1175.4	1175.4	1180.5	1180.5	1180.4
10+00	1170.20	1170.20	1170.20						

Note: Stations refer to distance in feet from weir crest.
Spillway bays and piers are numbered from right to left.

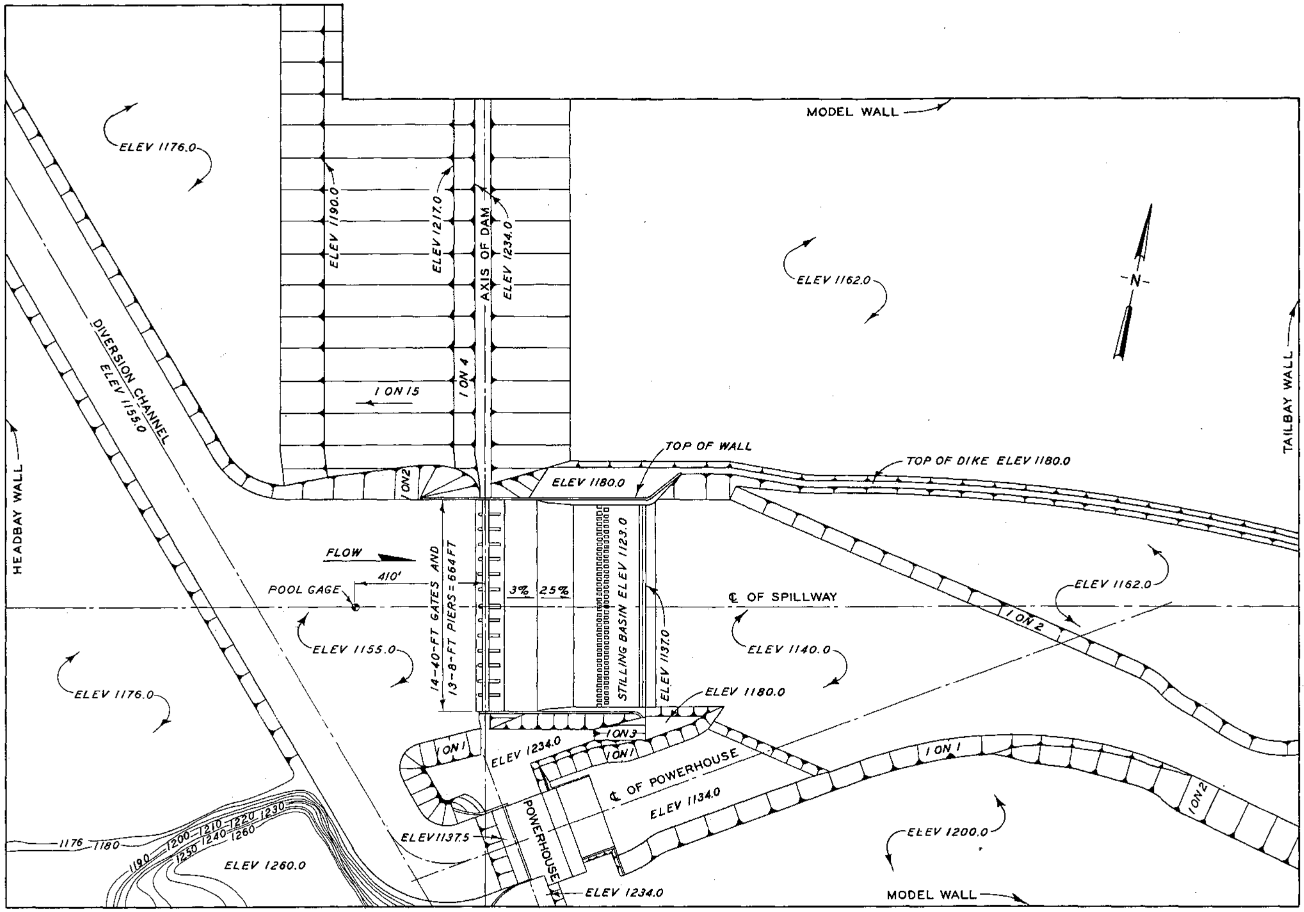
Table 9

Water-surface Elevations -- Chute, Type 1-B Stilling Basin, and Exit Channel

Discharge, 626,000 cfs

	Tailwater Elevation, 1176.3			Tailwater Elevation, 1180.7			Tailwater Elevation, 1185.0		
Station	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall	Bay No. 1 10 ft from Training Wall	Bay No. 8 Center Line	Bay No. 14 10 ft from Training Wall
1+75	1164.9	1167.7	1167.3 1162.9						
2+00	1163.4	1163.0	1163.1				1167.0	1167.0	1172.0
2+10				1164.0	1164.0	1166.0			
2+20	1159.1	1157.0	1156.8						
2+25	1158.5	1162.5	1158.0	1166.0	1167.0	1168.0	1175.0	1176.5	1175.0
2+50	1164.5	1166.0	1165.0	1170.0	1171.0	1169.5	1178.5	1178.5	1178.5
3+00	1169.5	1171.0	1169.5	1173.0	1172.5	1171.5	1179.5	1180.0	1181.0
3+50	1177.0	1177.0	1177.0	1179.0	1178.5	1179.0	1183.0	1183.0	1184.0
4+00	1181.0	1184.0	1180.0	1183.5	1185.5	1183.0	1186.5	1187.0	1185.0
4+50	1181.5	1182.0	1181.5	1184.0	1184.5	1183.5	1188.5	1188.5	1186.0
5+00	1182.0	1180.0	1179.5	1183.5	1183.5	1181.5	1187.0	1186.5	1185.0
5+50	1181.5	1180.0	1174.0	1183.5	1183.5	1178.5	1186.5	1185.5	1185.5
6+00	1178.0	1176.3	1177.0	1182.0	1181.5	1181.5	1185.0	1184.5	1184.5
6+50	1176.5	1176.3	1176.5				1185.0	1185.0	1185.0
7+00	1176.0	1176.3	1178.0	1180.7	1181.5	1182.0	1185.0	1187.0	1186.0
7+50	1176.0	1176.3	1177.5						
8+00	1176.0	1176.3	1177.0	1180.7	1181.5	1182.0	1185.0	1186.0	1186.0
8+50	1176.0	1176.8	1176.3						
9+00	1176.3	1175.0	1175.0	1180.7	1180.7	1180.7	1185.0	1185.0	1185.0
10+00	1175.5	1176.3	1173.0	1180.7	1180.7	1180.7	1185.0	1185.0	1185.0
11+50	1176.3	1177.5	1176.3						

Note: Stations refer to distance in feet from weir crest.
Spillway bays and piers are numbered from right to left.



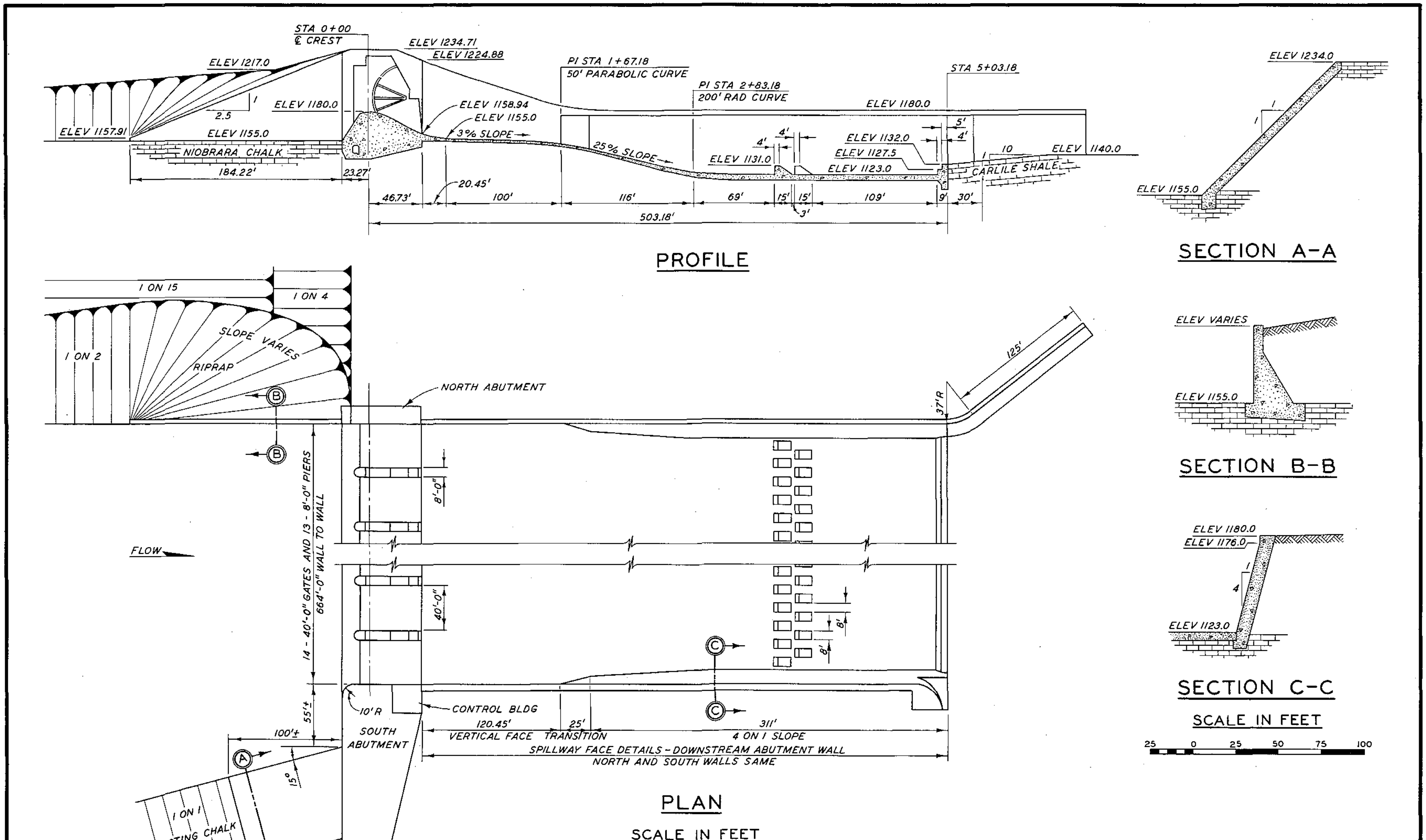
GENERAL PLAN

SCALE

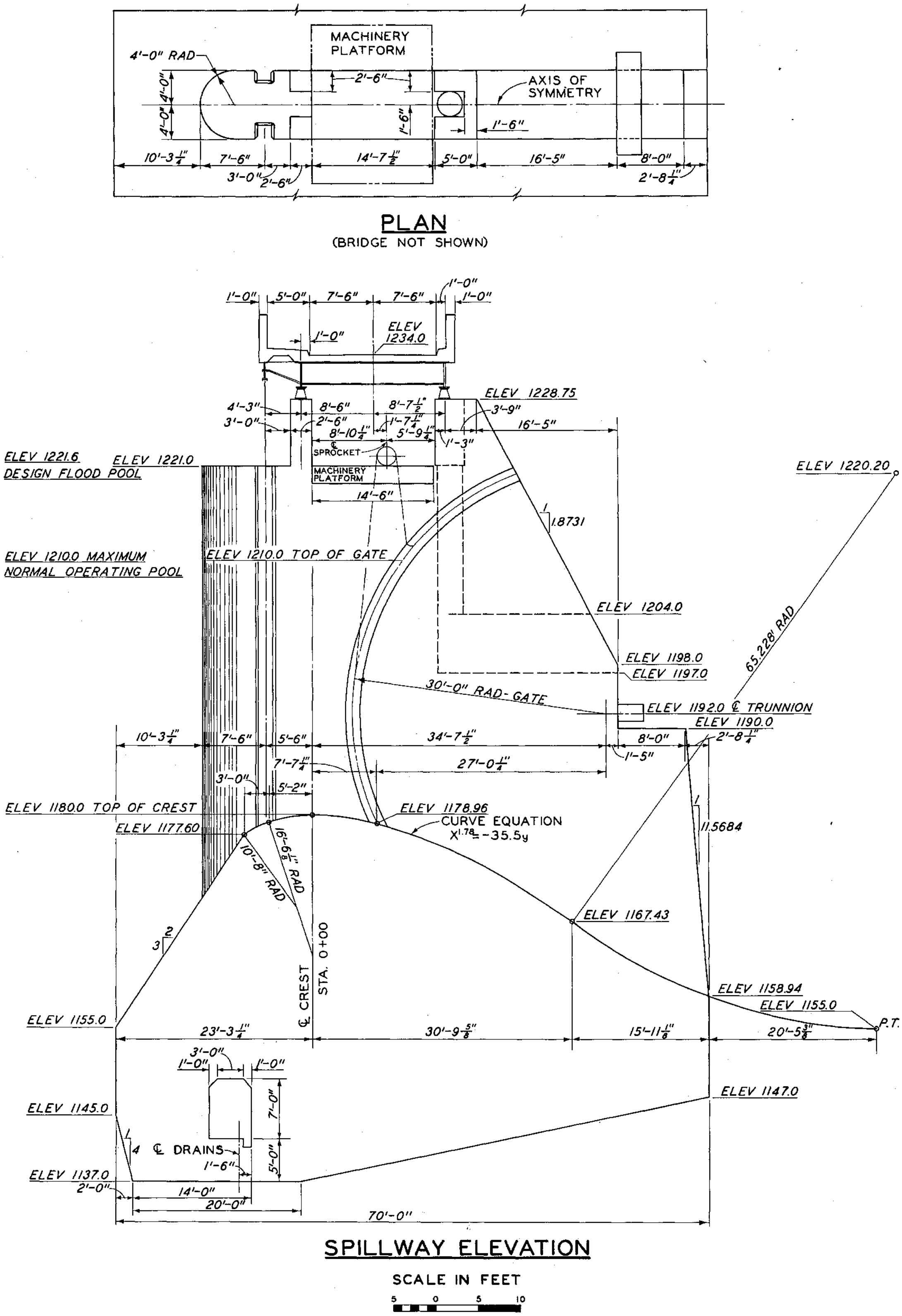
200 0 200 400 600 FT

PLATE 1

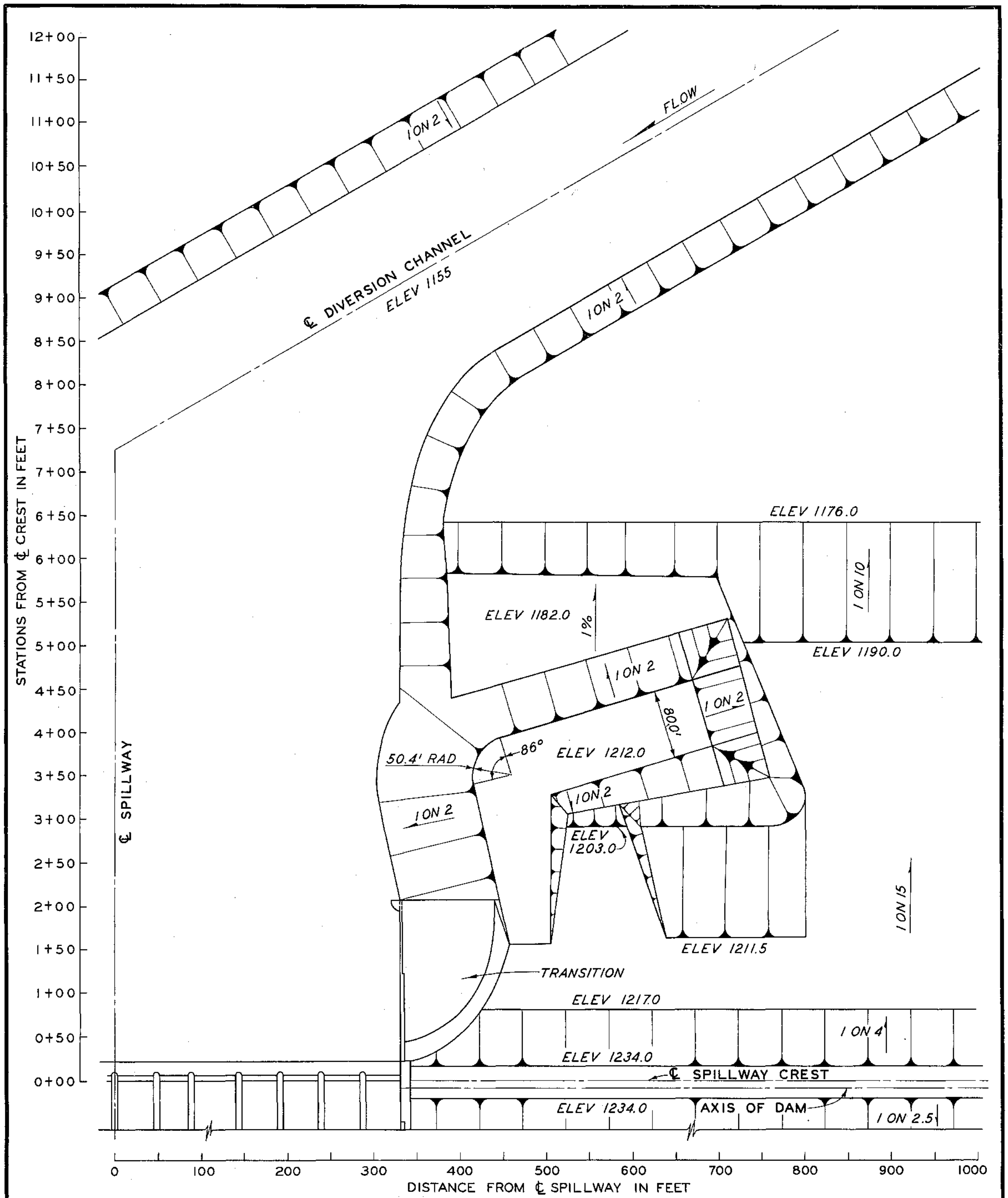
PLATE 2



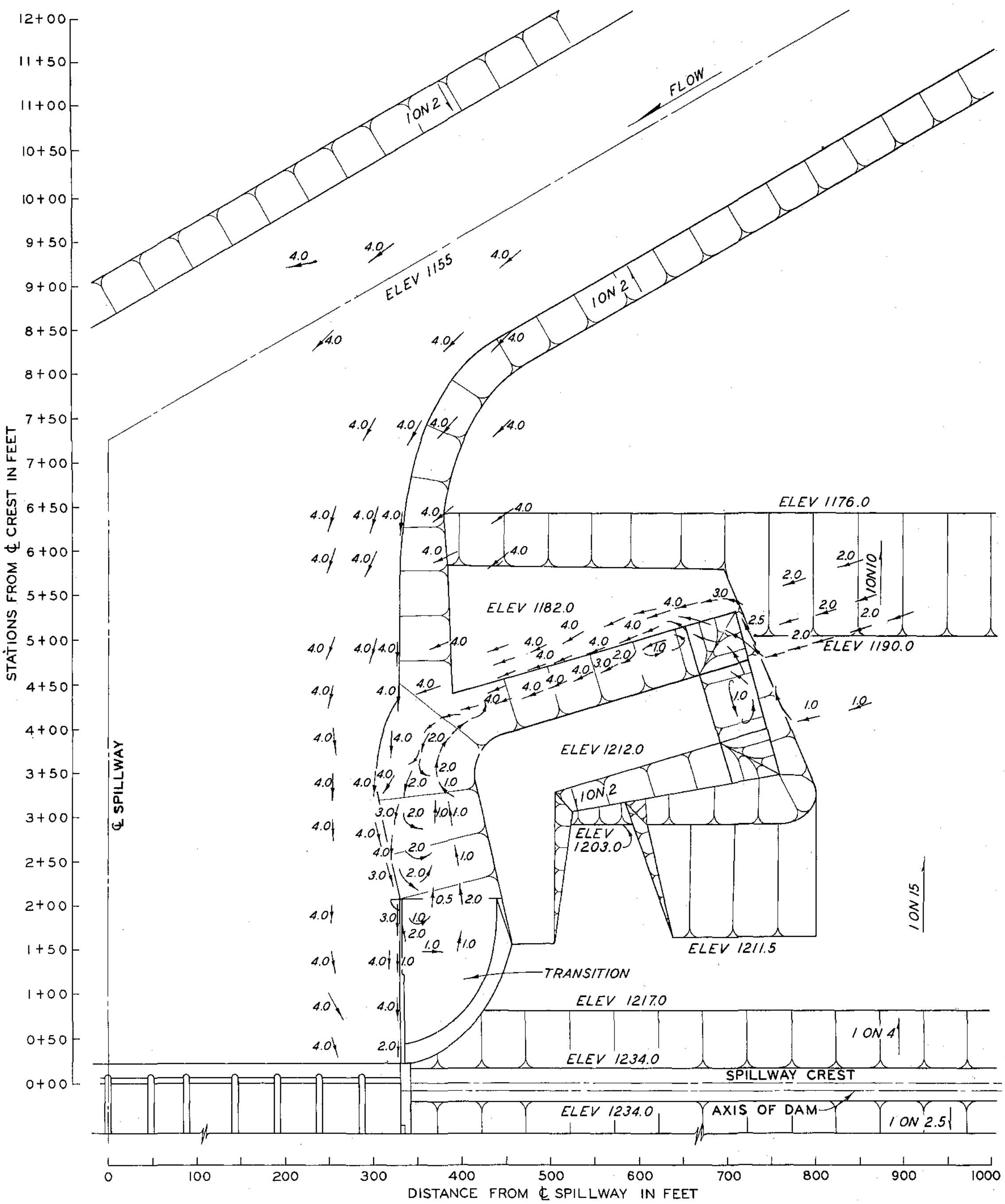
GENERAL PLAN AND PROFILE



DETAILS OF SPILLWAY WEIR AND PIER



DETAILS OF CHALK DIKE
LEFT ABUTMENT



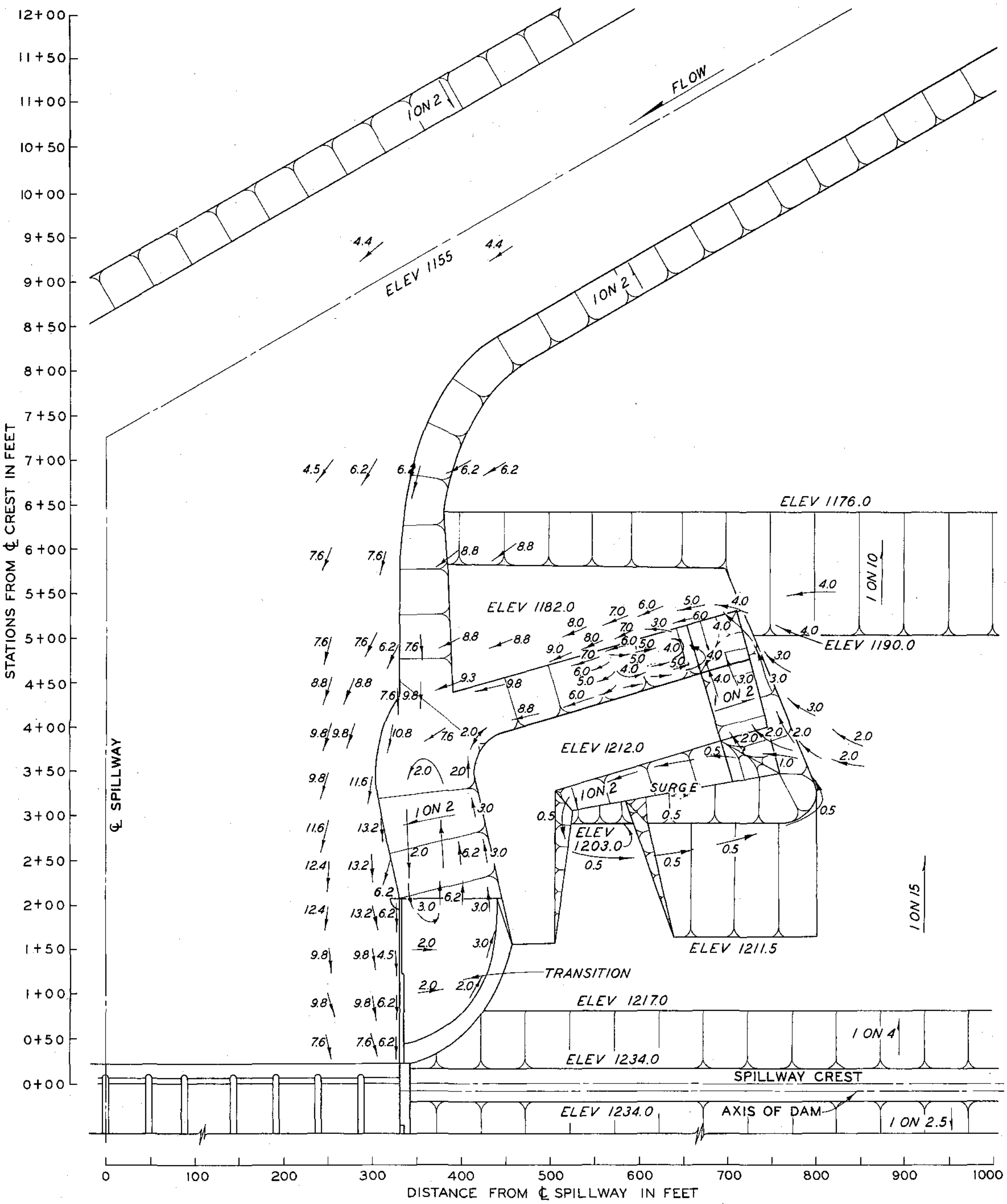
TEST CONDITIONS

Q 100,000 CFS
POOL ELEV 1193.7 FT

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND MEASURED 2 FEET OFF BOTTOM.

BOTTOM VELOCITIES

CHALK DIKE AT LEFT ABUTMENT
DISCHARGE 100,000 CFS



TEST CONDITIONS

Q 364,000 CFS

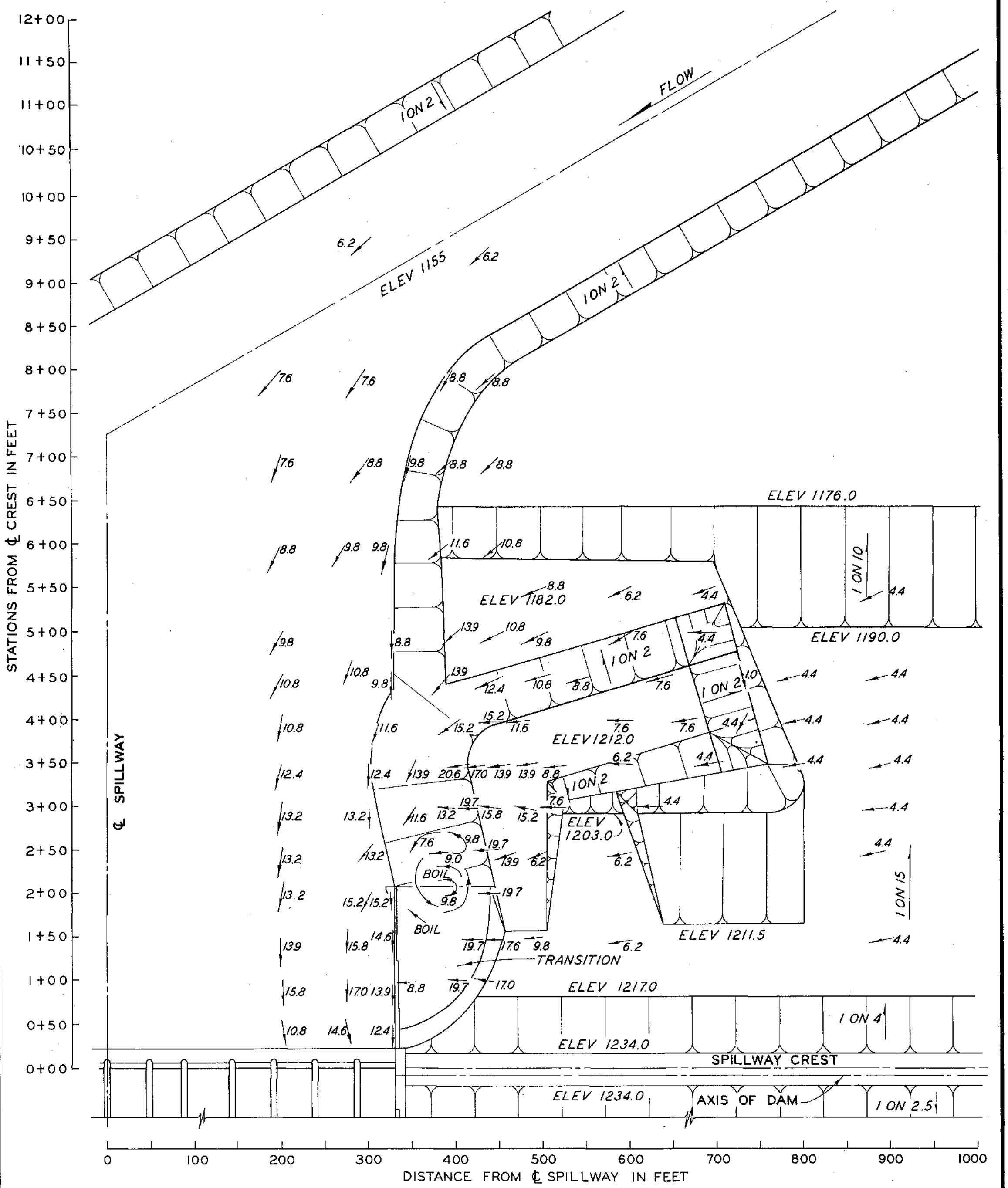
POOL ELEV 1211.0 FT

NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND MEASURED 2 FEET OFF BOTTOM.

BOTTOM VELOCITIES

CHALK DIKE AT LEFT ABUTMENT

DISCHARGE 364,000 CFS

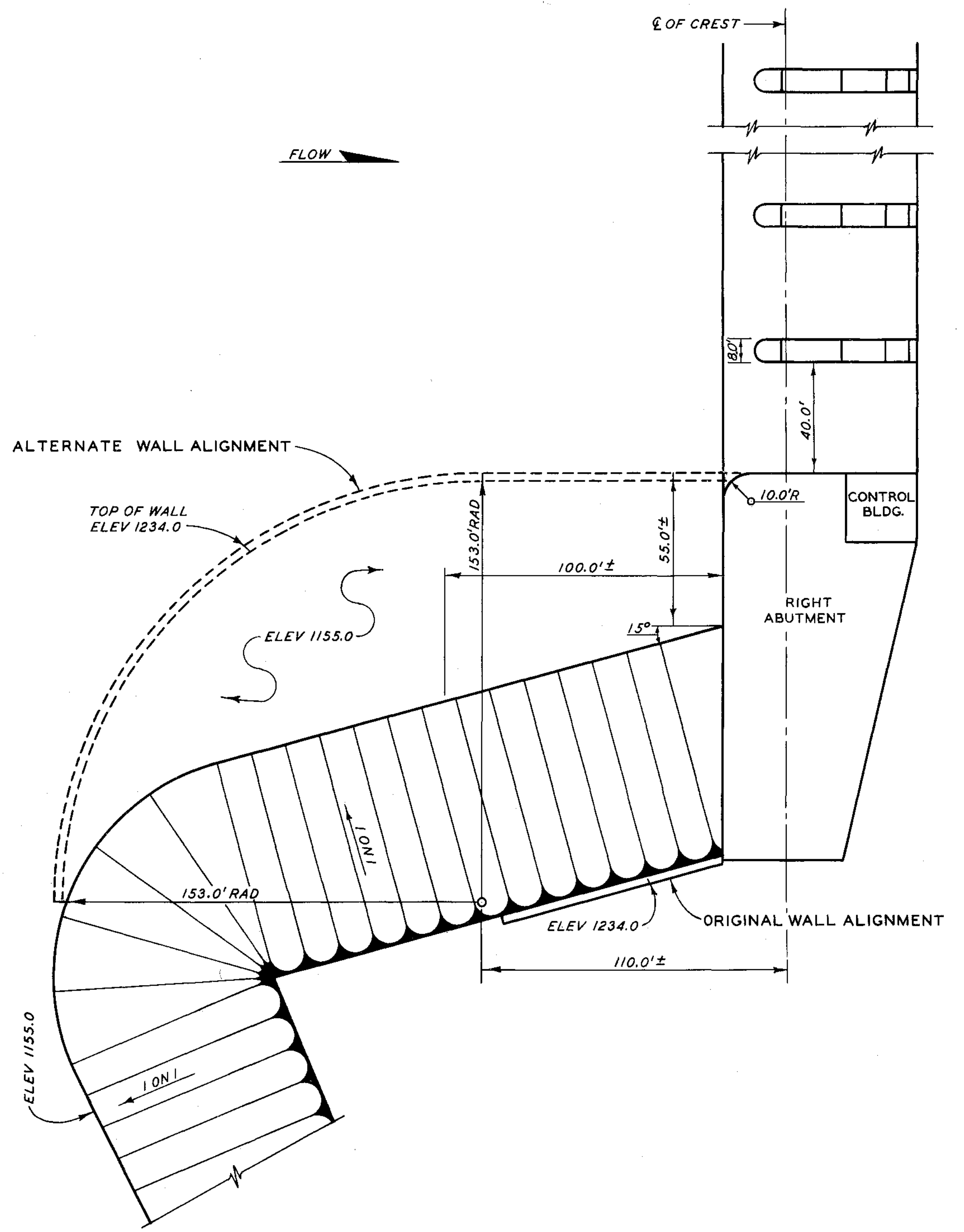


TEST CONDITIONS

Q	626,000 CFS
POOL ELEV	1223.5 FT

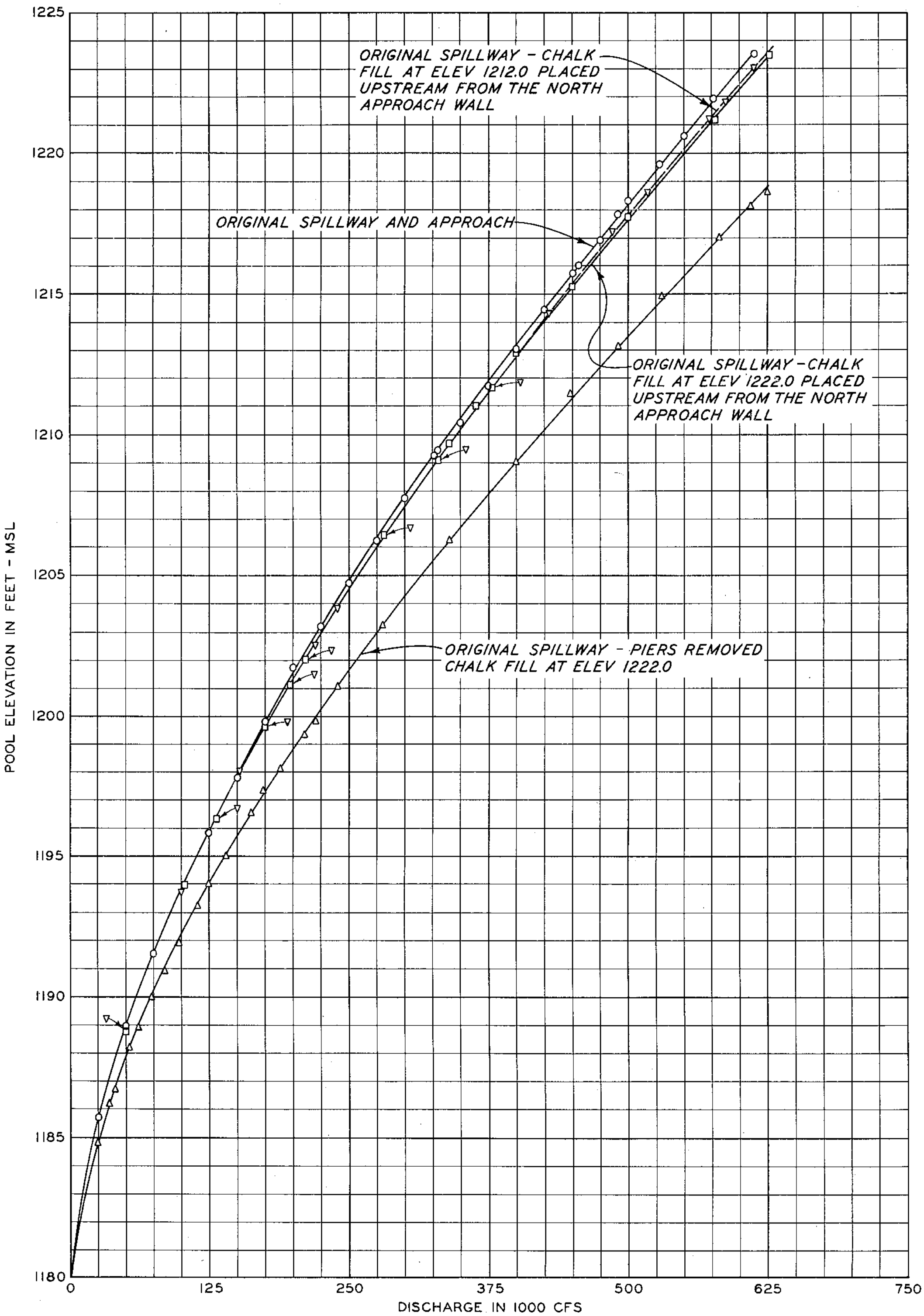
NOTE: VELOCITIES ARE IN PROTOTYPE FEET PER SECOND MEASURED 2 FEET OFF BOTTOM.

BOTTOM VELOCITIES
CHALK DIKE AT LEFT ABUTMENT
DISCHARGE 626,000 CFS



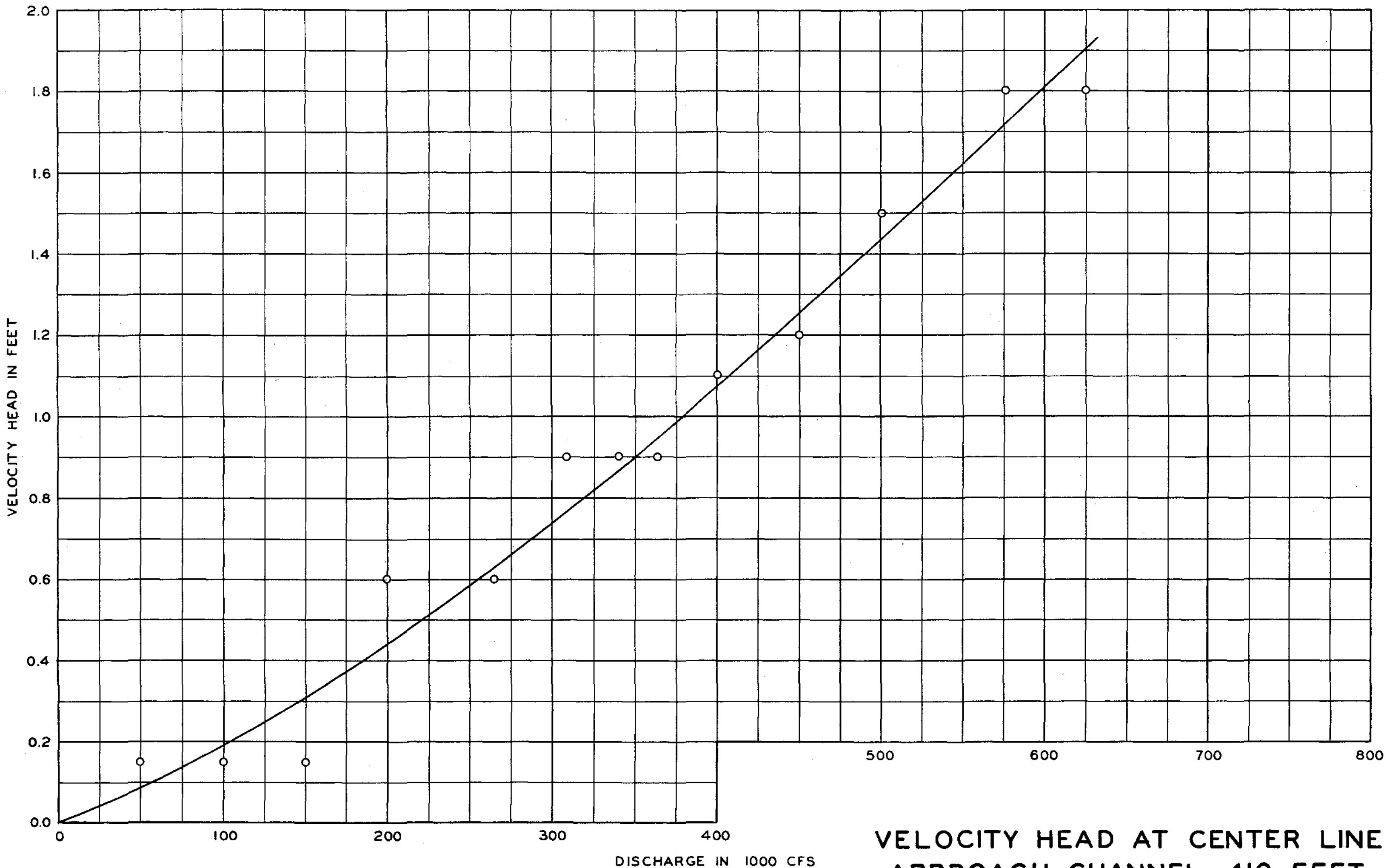
DETAILS OF RIGHT ABUTMENT
AND ALTERNATE APPROACH WALL

PLATE 8

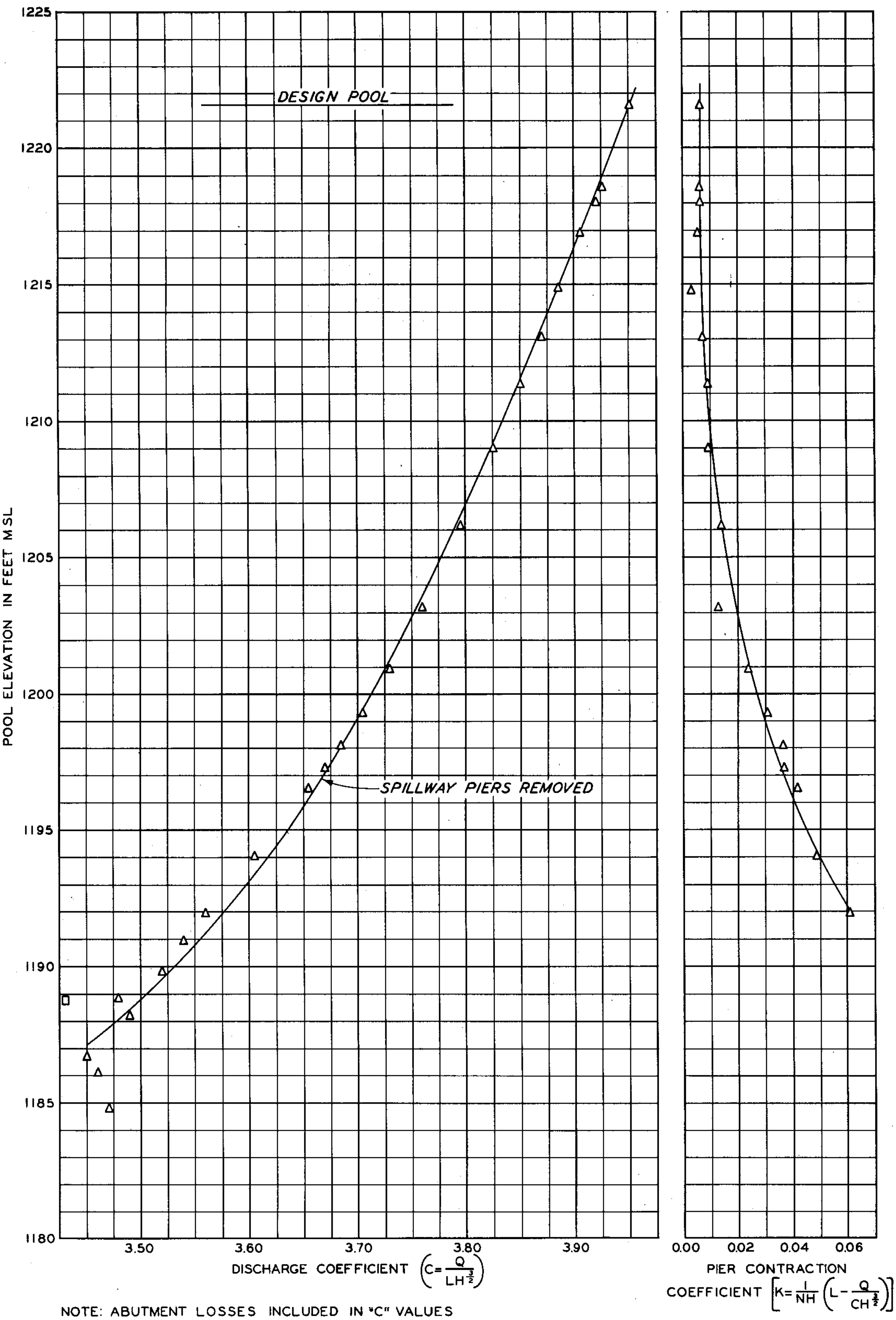


NOTE: ALL GATES OPEN FULL.
POOL ELEVATION CORRECTED FOR VELOCITY OF APPROACH.

SPILLWAY RATING CURVES

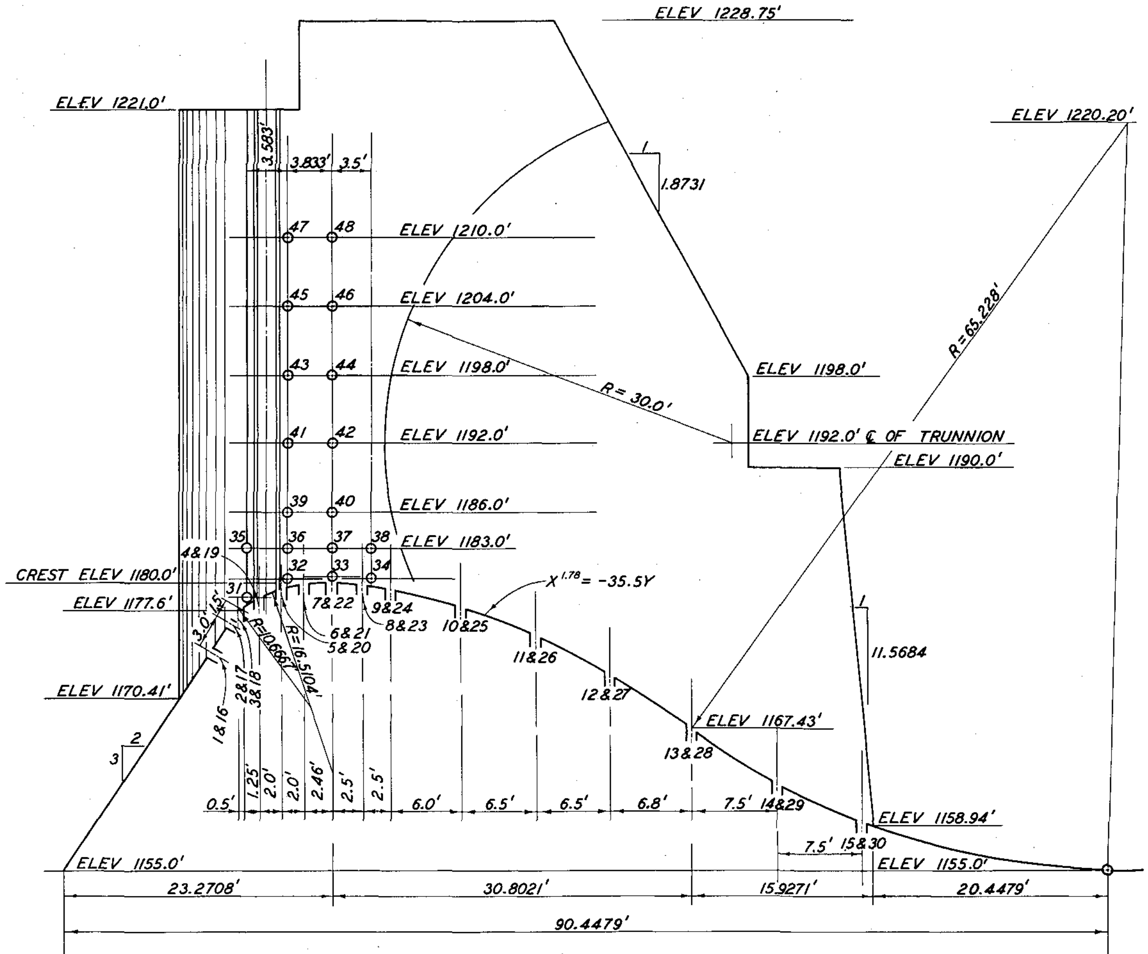


VELOCITY HEAD AT CENTER LINE
APPROACH CHANNEL 410 FEET
UPSTREAM FROM WEIR CREST



NOTE: ABUTMENT LOSSES INCLUDED IN "C" VALUES
"N"=26 FOR PIER CONTRACTIONS.

SPILLWAY COEFFICIENTS



PIEZOMETER NUMBER	PIEZOMETER ELEVATION
1 & 16	1173.7
2 & 17	1176.3
3 & 18	1178.0
4 & 19	1178.6
5 & 20	1179.3
6 & 21	1179.8
7 & 22	1180.0
8 & 23	1179.8
9 & 24	1179.2
10 & 25	1177.8
11 & 26	1175.3
12 & 27	1171.9
13 & 28	1167.4
14 & 29	1162.7
15 & 30	1159.2
31	1178.5
32	1180.0
33	1180.5
34	1180.3
35 & 36	1183.0
37 & 38	1183.0
39 & 40	1186.0
41 & 42	1192.0
43 & 44	1198.0
45 & 46	1204.0
47 & 48	1210.0

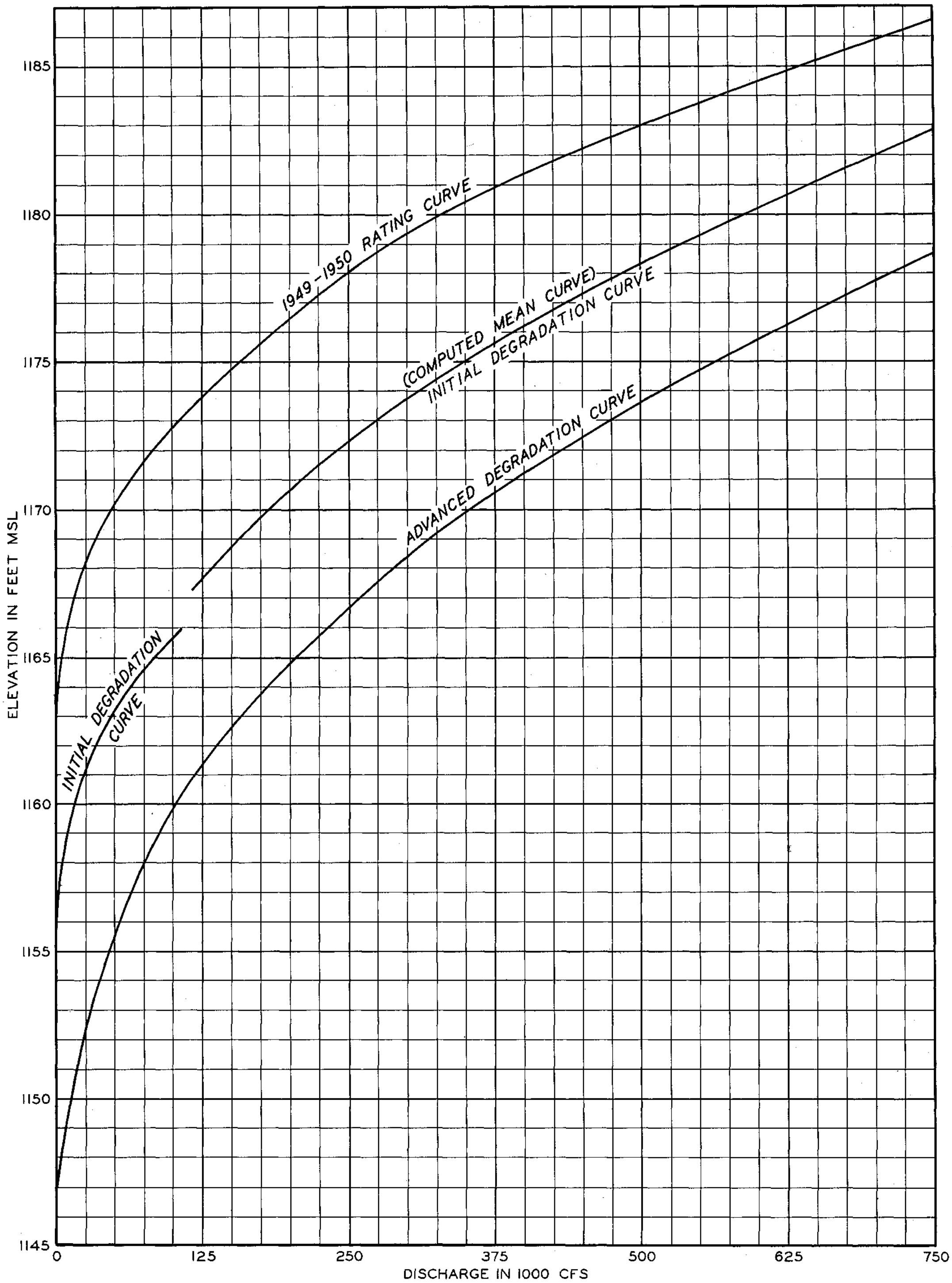
NOTE: PIEZOMETER 1 THROUGH 15 LOCATED 24.0' LEFT OF ℄ OF SPILLWAY.
PIEZOMETER 16 THROUGH 30 LOCATED 42.5' LEFT OF ℄ OF SPILLWAY.
PIEZOMETER 31 THROUGH 34 LOCATED 4.0' LEFT OF ℄ OF SPILLWAY ON PIER NO. 7.
PIEZOMETER 35 THROUGH 48 LOCATED 44.0' LEFT OF ℄ OF SPILLWAY ON PIER NO. 8.
SPILLWAY BAYS AND PIERS ARE NUMBERED FROM RIGHT TO LEFT.

PIEZOMETER LOCATIONS

WEIR AND CREST PIERS

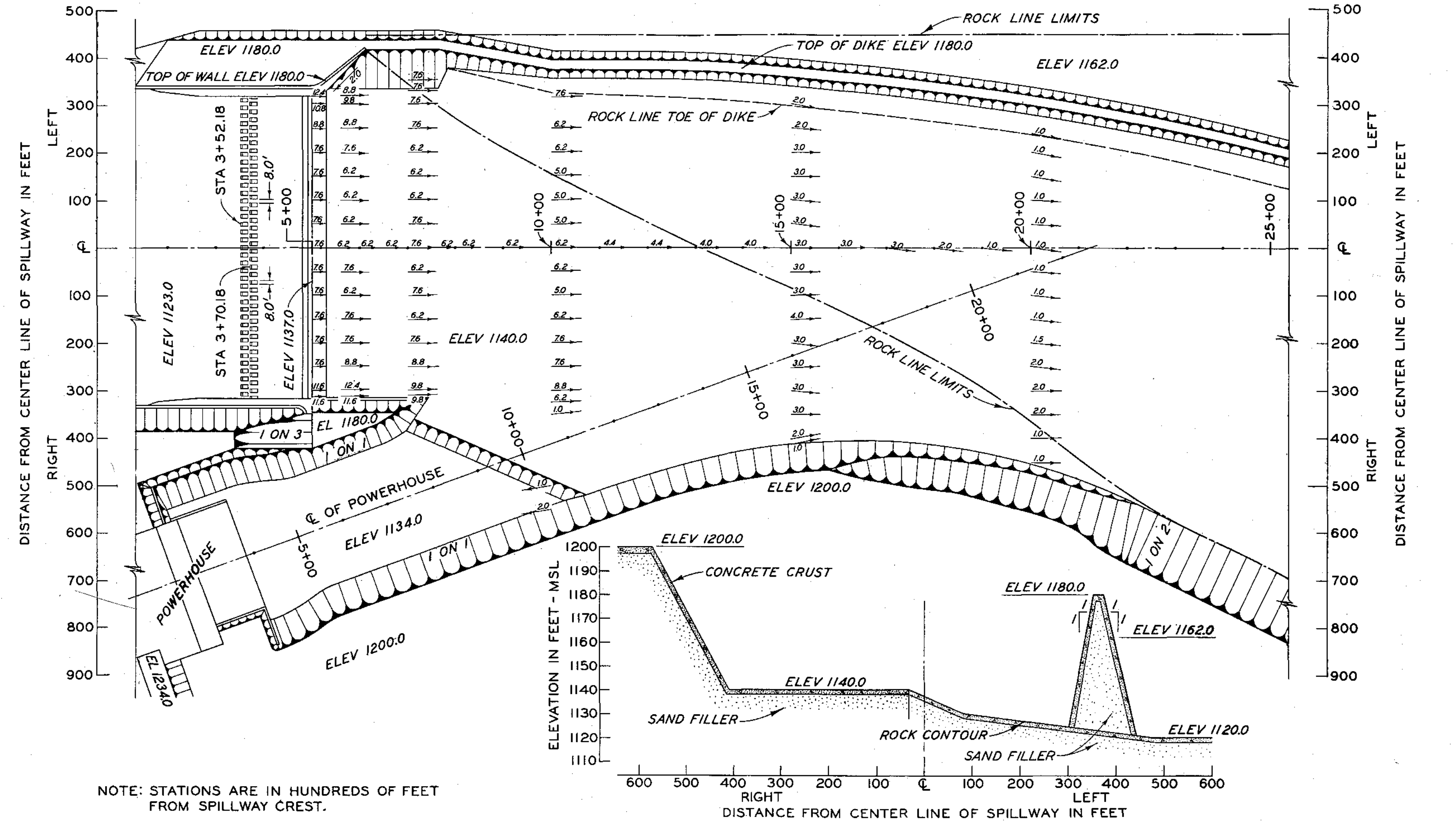
SCALE

10 0 10 20 FT



TAILWATER RATING CURVES

PLATE 14



SECTION STATION 15+00

NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

VELOCITIES ARE IN FT PER SEC IN PROTOTYPE MEASURED 2 FT OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR IN ACCORDANCE WITH SECTION AT STA 15+00.

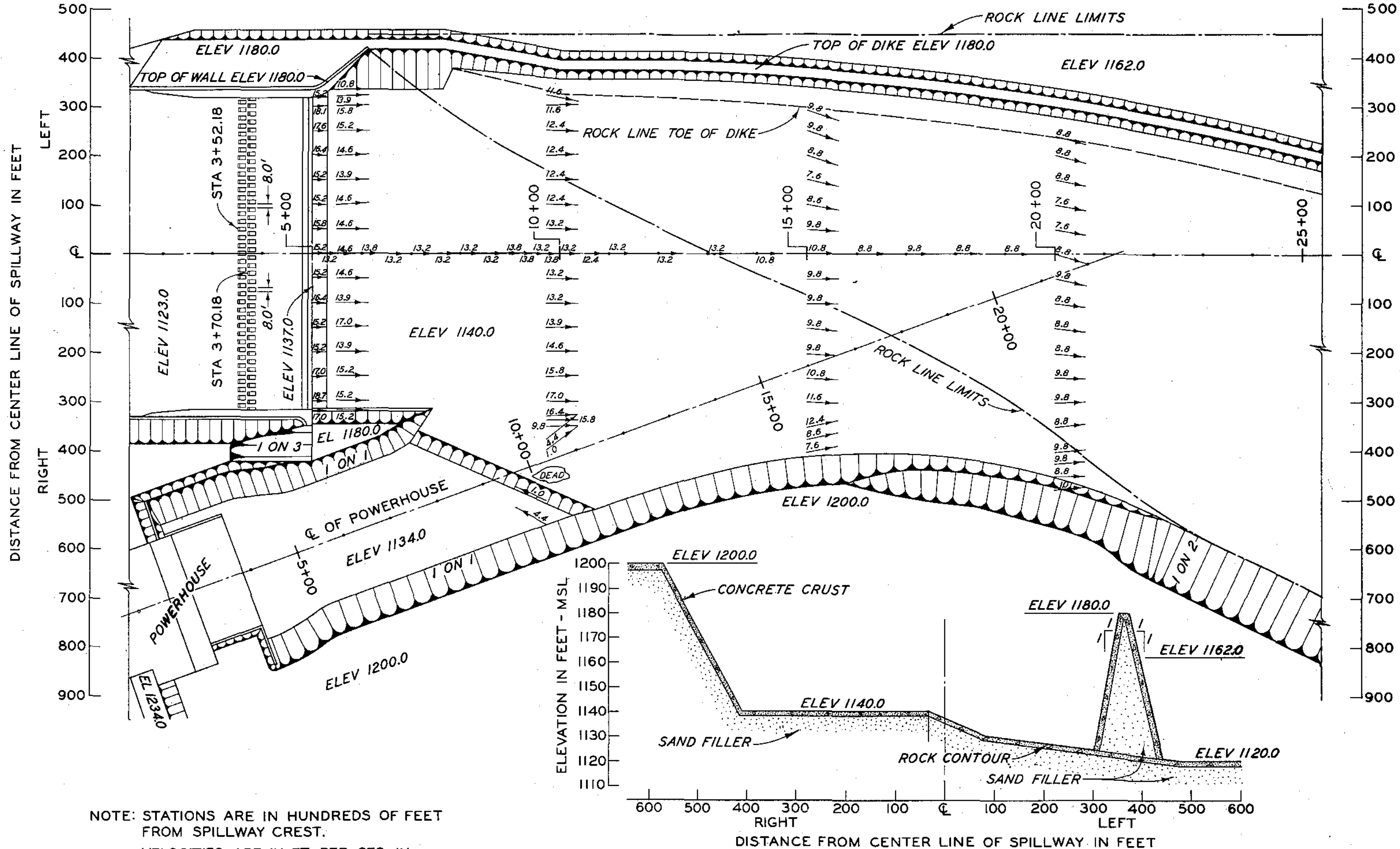
TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
14-FT END SILL - STA 4+83.18

BOTTOM VELOCITIES

TYPE I STILLING BASIN

DISCHARGE 100,000 CFS
TAILWATER ELEV 1159.8 FT



SECTION STATION 15+00

NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

VELOCITIES ARE IN FT PER SEC IN PROTOTYPE MEASURED 2 FT OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR IN ACCORDANCE WITH SECTION AT STA 15+00.

TEST CONDITIONS

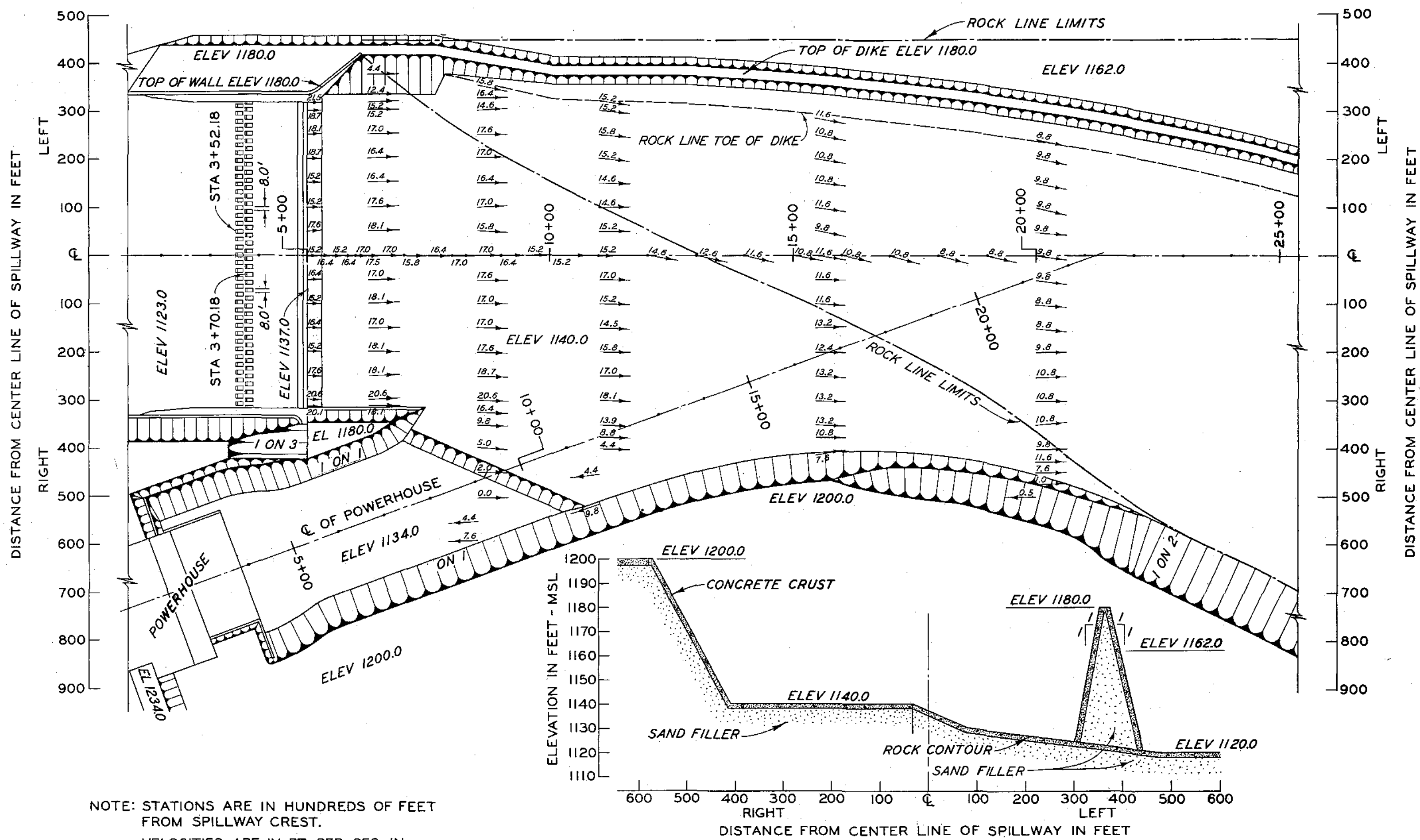
ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
14-FT END SILL - STA 4+83.18

BOTTOM VELOCITIES

TYPE I STILLING BASIN

DISCHARGE 364,000 CFS
TAILWATER ELEV 1175.4 FT

PLATE 15



SECTION STATION 15+00

NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

VELOCITIES ARE IN FT PER SEC IN PROTOTYPE MEASURED 2 FT OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR IN ACCORDANCE WITH SECTION AT STA 15+00.

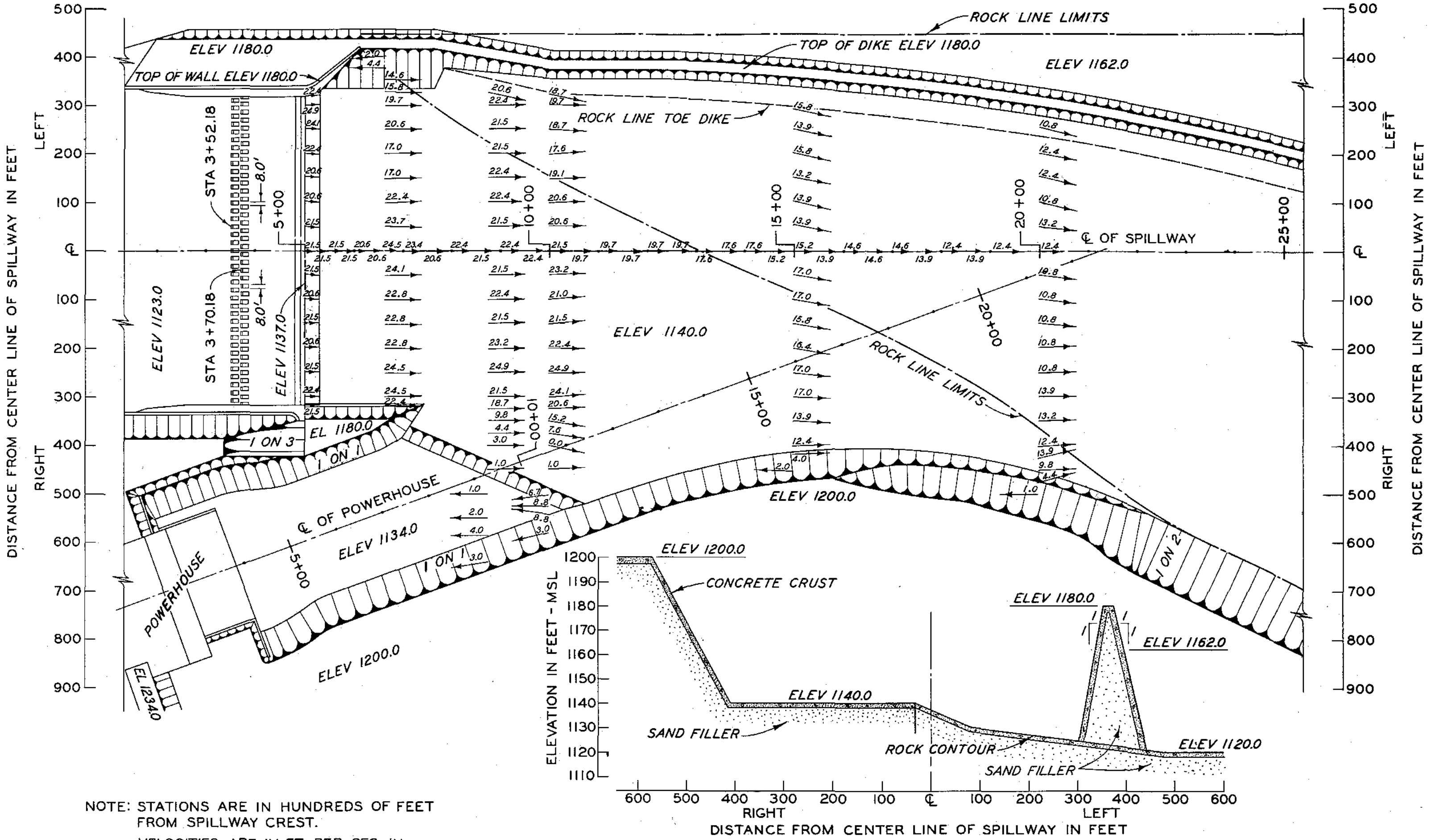
TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
14-FT END SILL - STA 4+83.18

BOTTOM VELOCITIES

TYPE I STILLING BASIN

DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT



SECTION STATION 15+00

NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

VELOCITIES ARE IN FT PER SEC IN PROTOTYPE MEASURED 2 FT OFF BOTTOM.

BED MOLDED IN CEMENT MORTAR IN ACCORDANCE WITH SECTION AT STA 15+00.

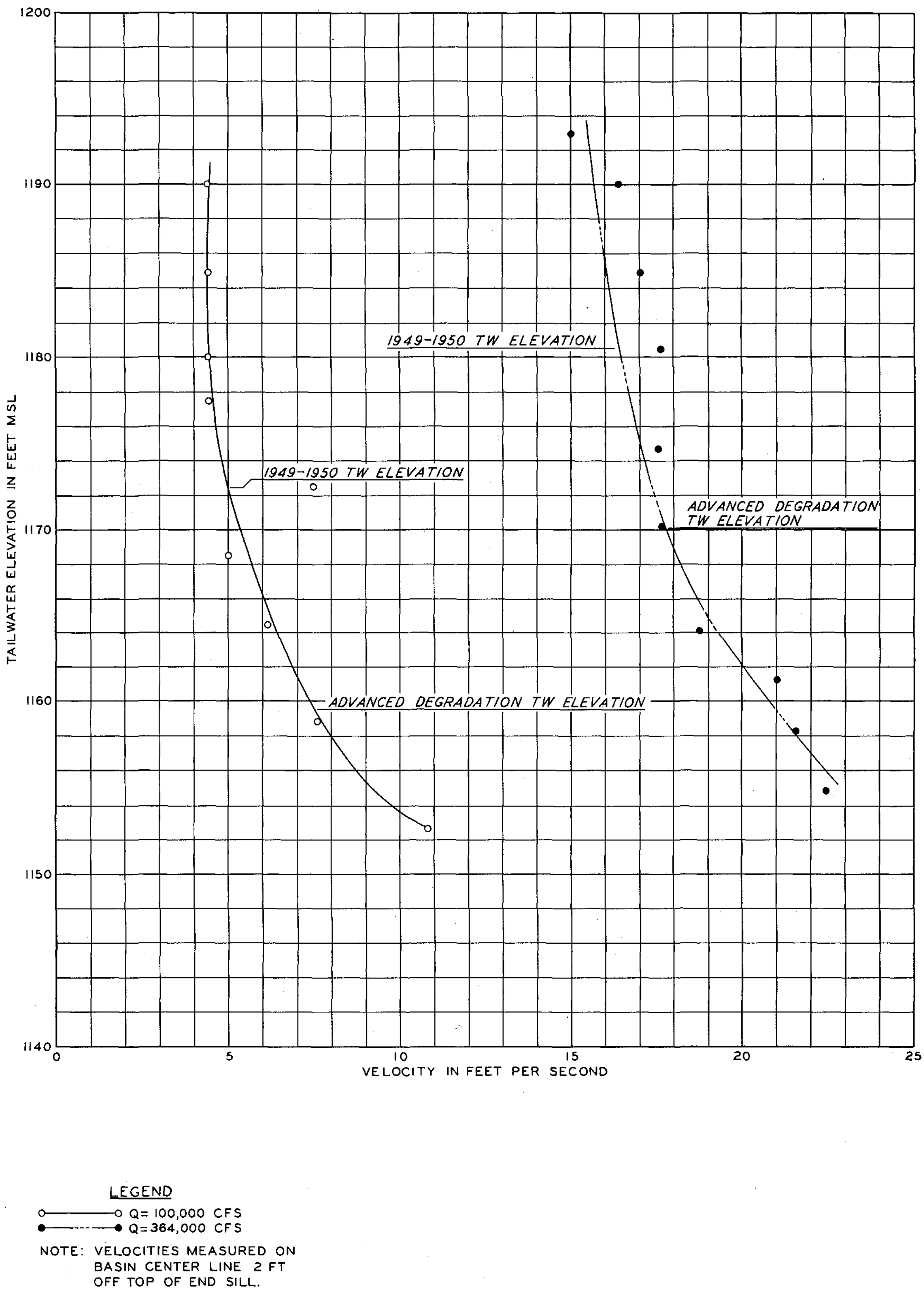
TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
14-FT END SILL - STA 4+83.18

BOTTOM VELOCITIES

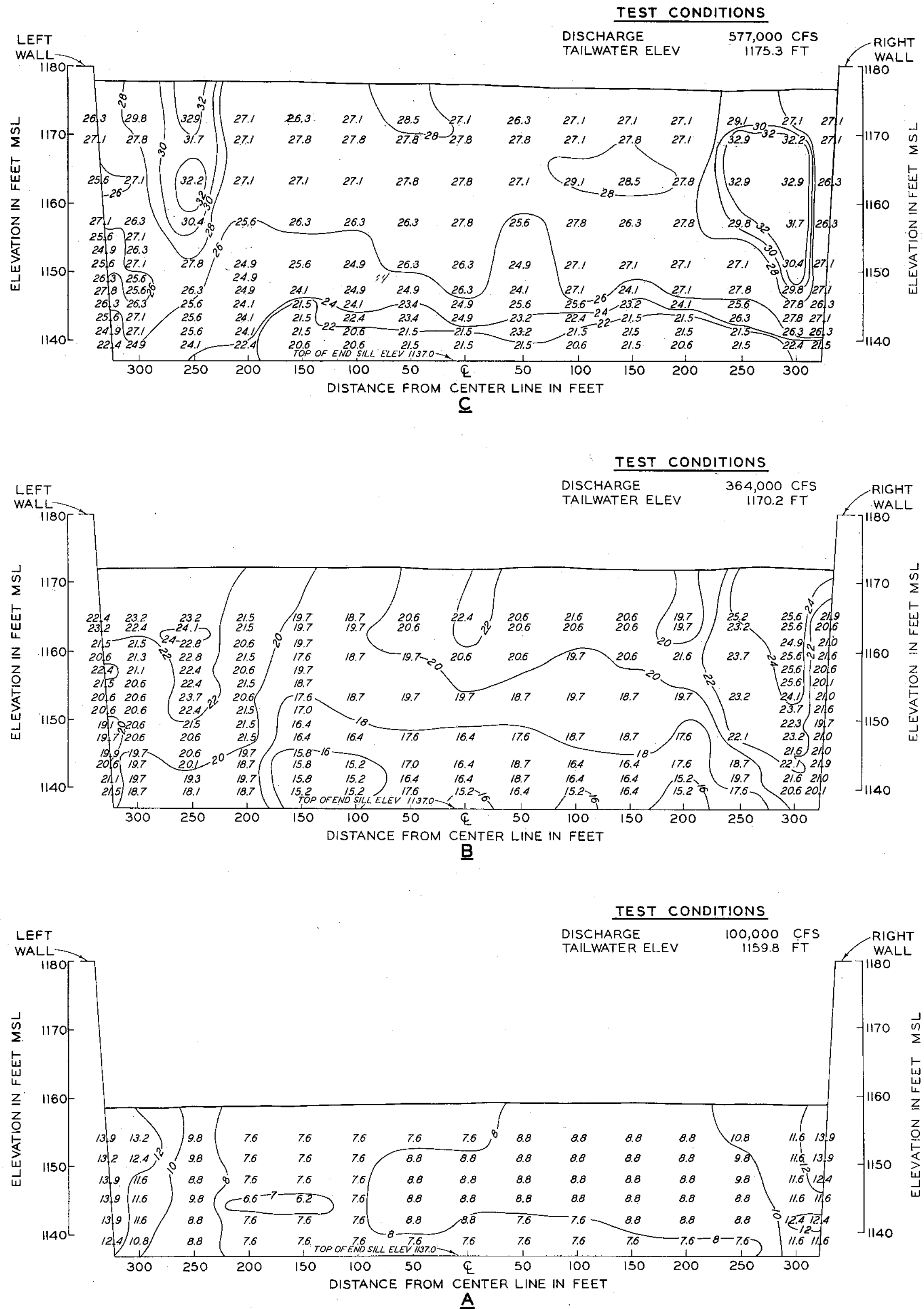
TYPE I STILLING BASIN

DISCHARGE 577,000 CFS
TAILWATER ELEV 1175.3 FT



TAILWATER-VELOCITY CURVES

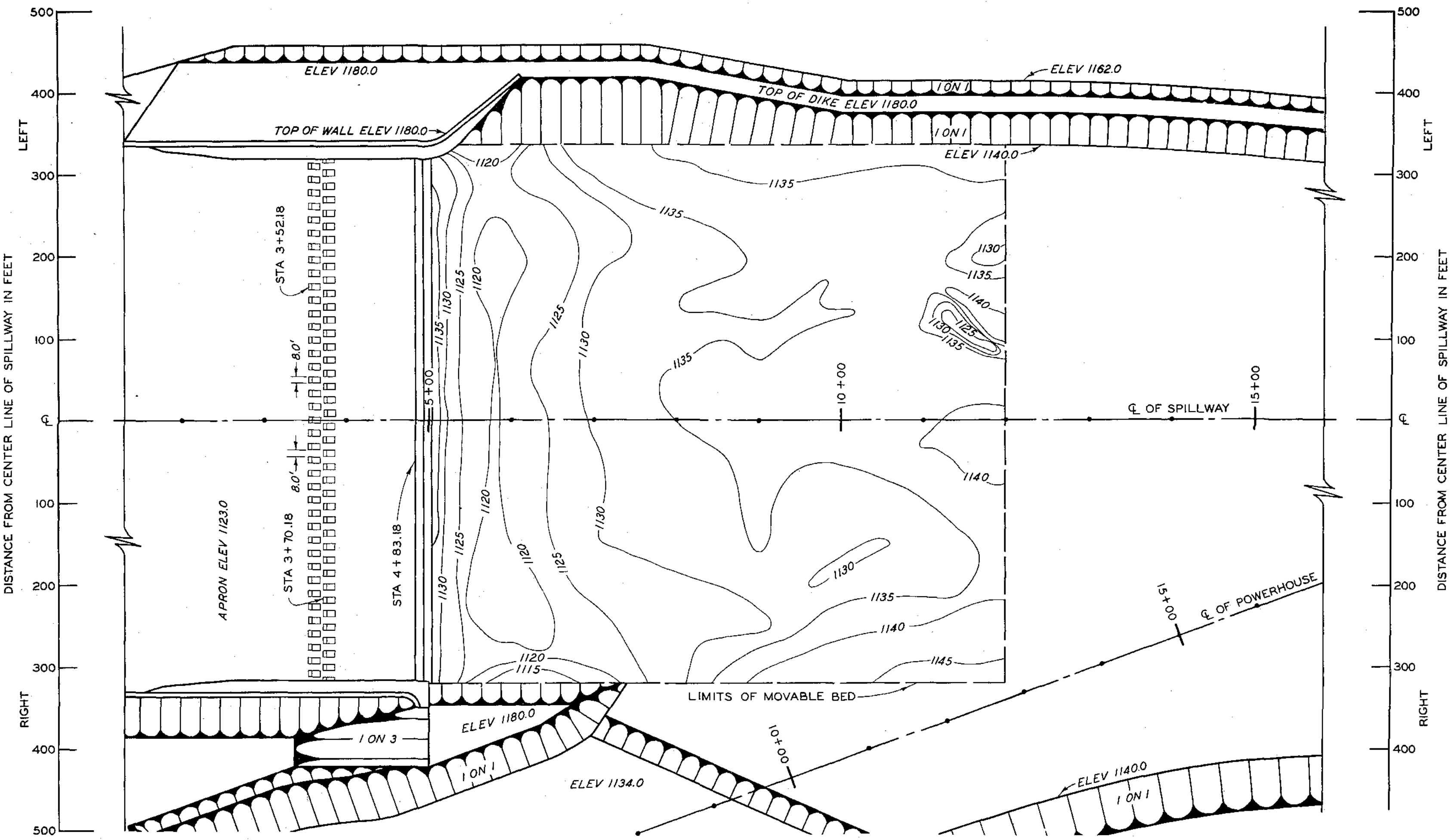
TYPE I STILLING BASIN



NOTE: VELOCITIES ARE IN FEET PER SECOND IN PROTOTYPE.

END SILL VELOCITIES

TYPE I STILLING BASIN



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1137.0 PRIOR TO START OF TEST.

TEST CONDITIONS

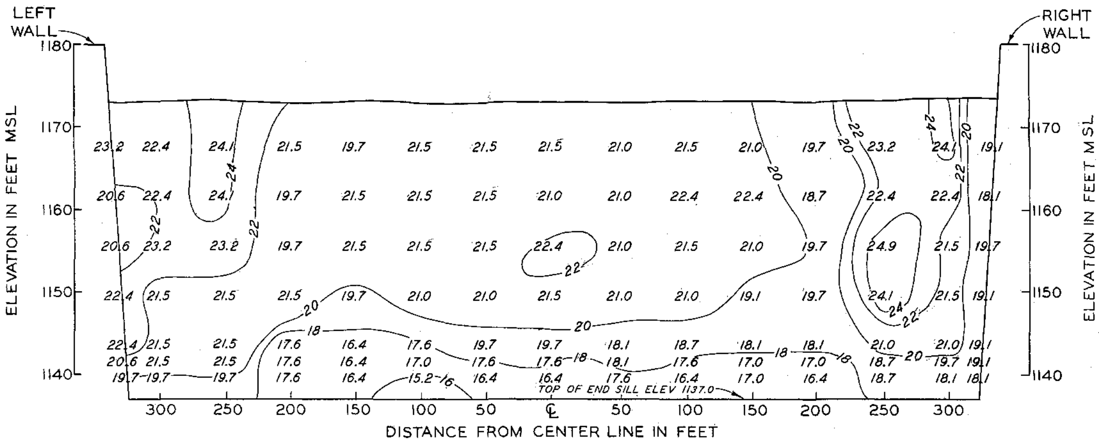
ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
14-FT END SILL - STA 4+83.18

SCOUR PATTERN

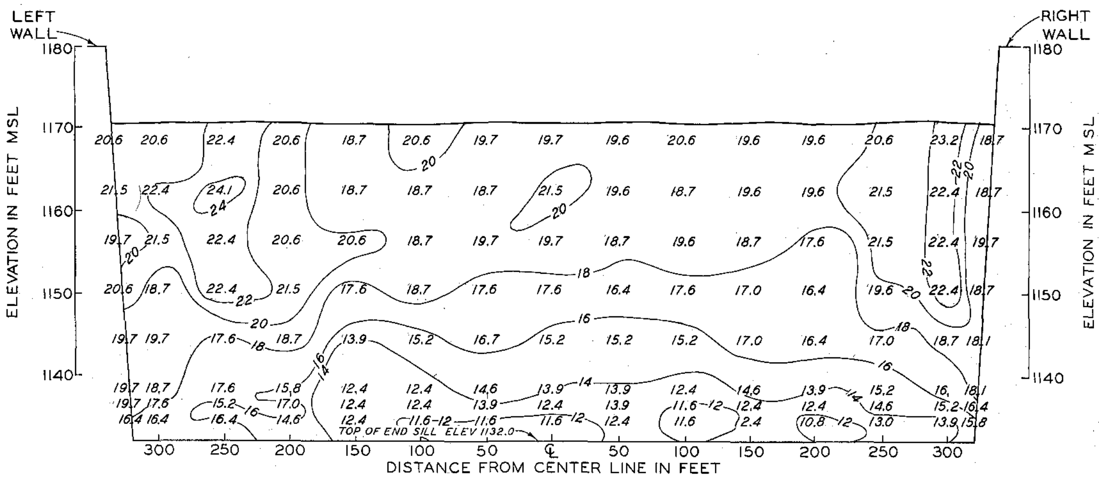
TYPE 1 STILLING BASIN

DISCHARGE 364,000 CFS

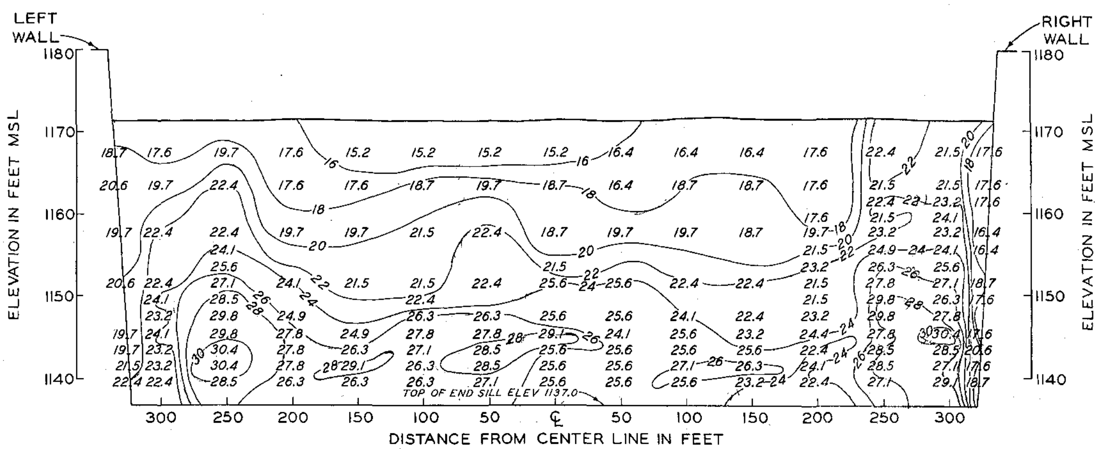
TAILWATER ELEV 1170.2 FT



TYPE I-C STILLING BASIN



TYPE I-B STILLING BASIN



TYPE I-A STILLING BASIN

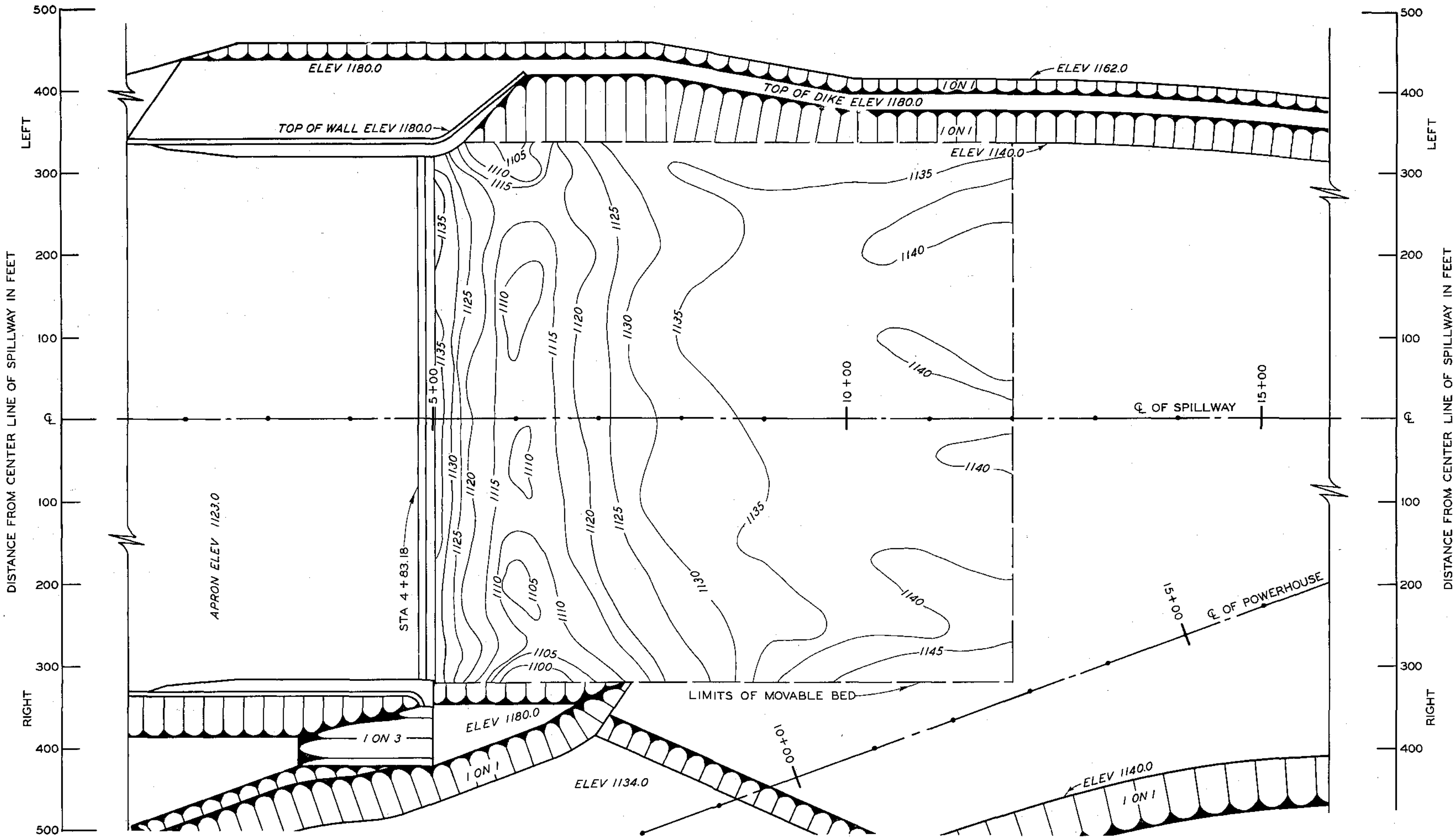
TEST CONDITIONS

DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT

NOTE: VELOCITIES ARE IN FEET PER SECOND IN PROTOTYPE.

END SILL VELOCITIES

TYPES I-A, I-B, AND I-C STILLING BASINS



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

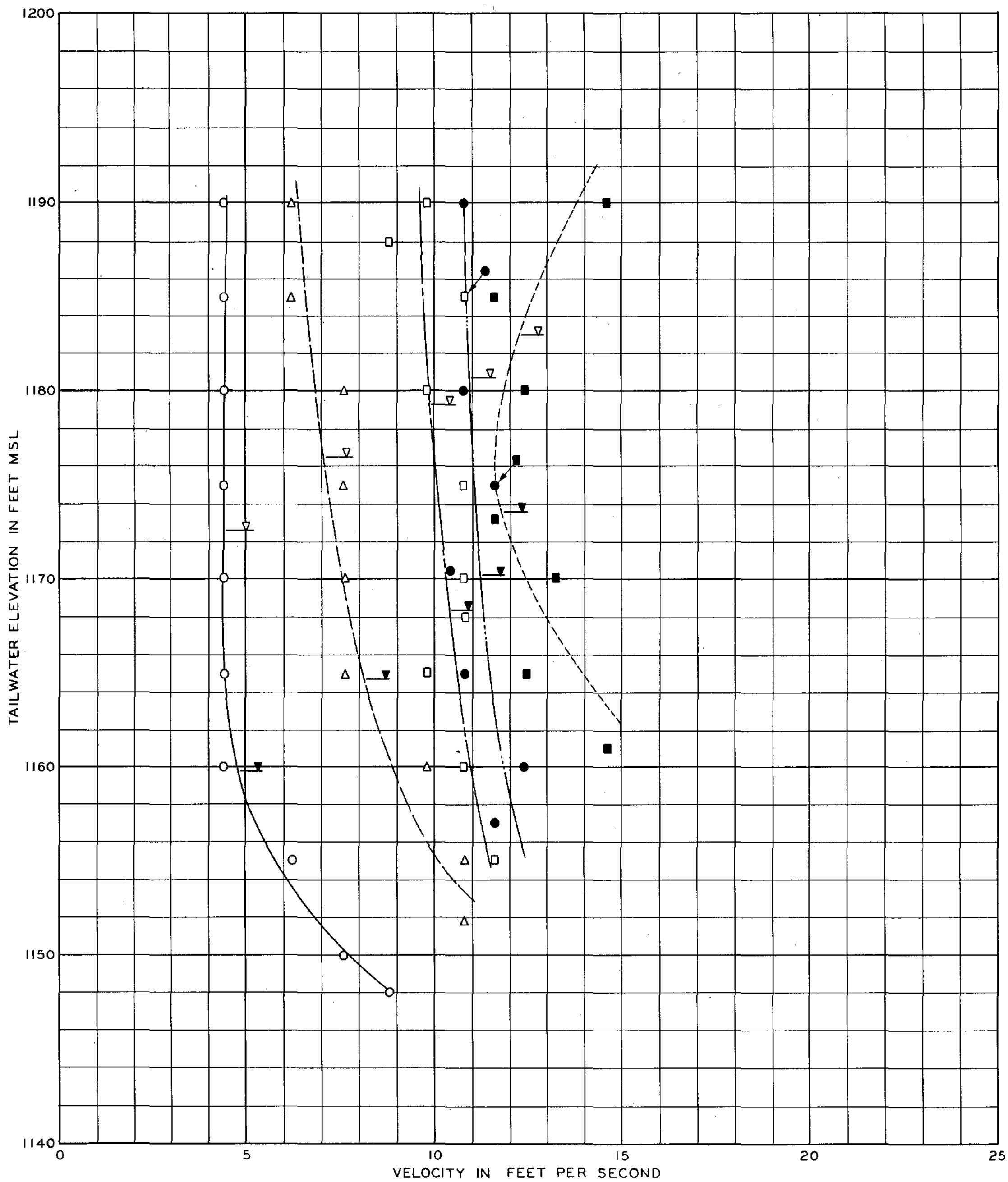
SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1137.0 PRIOR TO START OF TEST.

TEST CONDITIONS

BAFFLES REMOVED
14-FT END SILL-STA 4 + 83.18

SCOUR PATTERN

TYPE 1-A STILLING BASIN
DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT



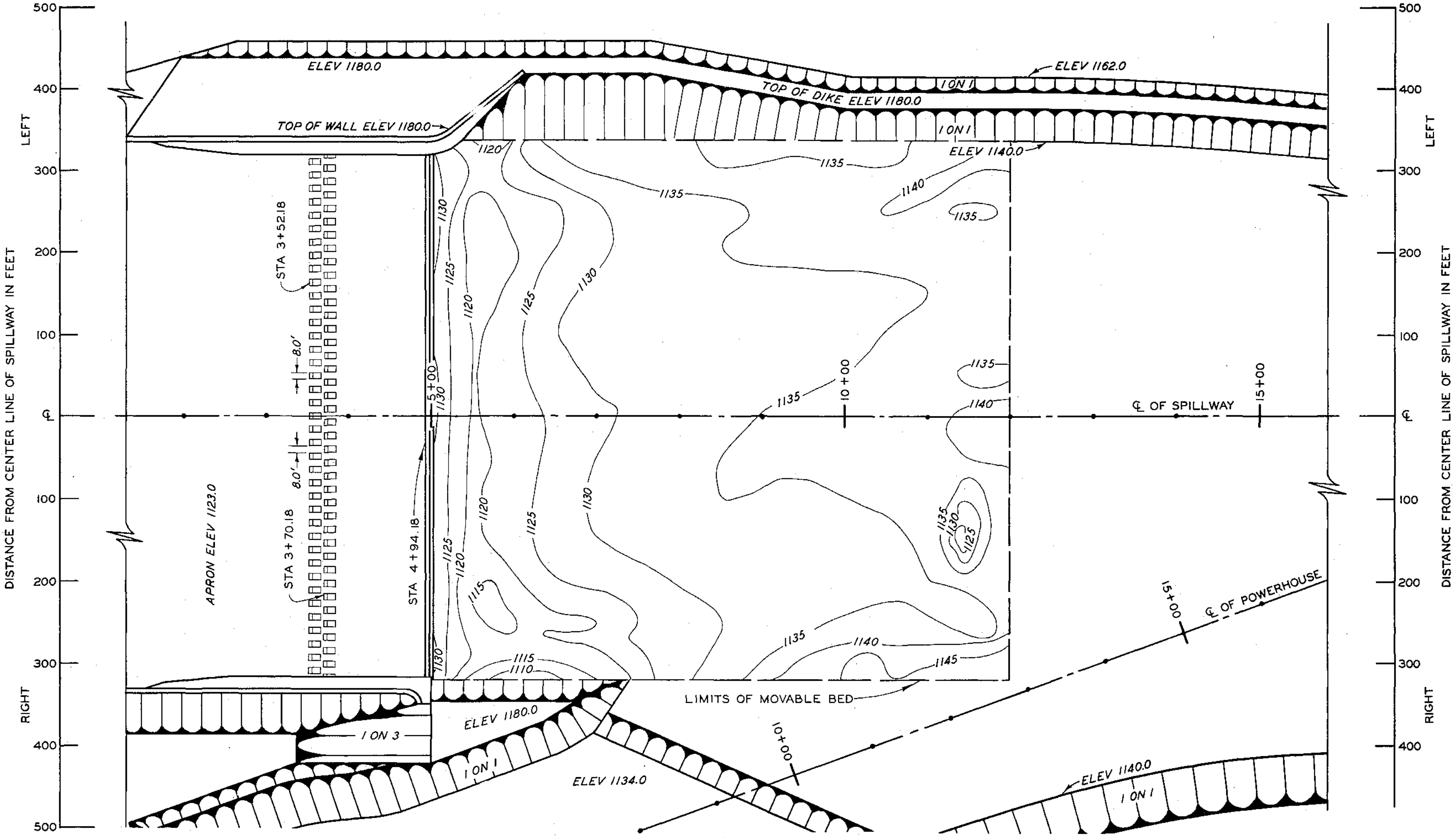
LEGEND

- Q= 100,000 CFS
- Q= 200,000 CFS
- Q= 300,000 CFS
- Q= 364,000 CFS
- Q= 500,000 CFS
- 1949-1950 TAILWATER ELEVATION
- ADVANCED DEGRADATION TAILWATER ELEVATION

NOTE: VELOCITIES MEASURED ON BASIN CENTER LINE 2 FT OFF TOP OF END SILL.

TAILWATER-VELOCITY CURVES

TYPE I-B STILLING BASIN



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

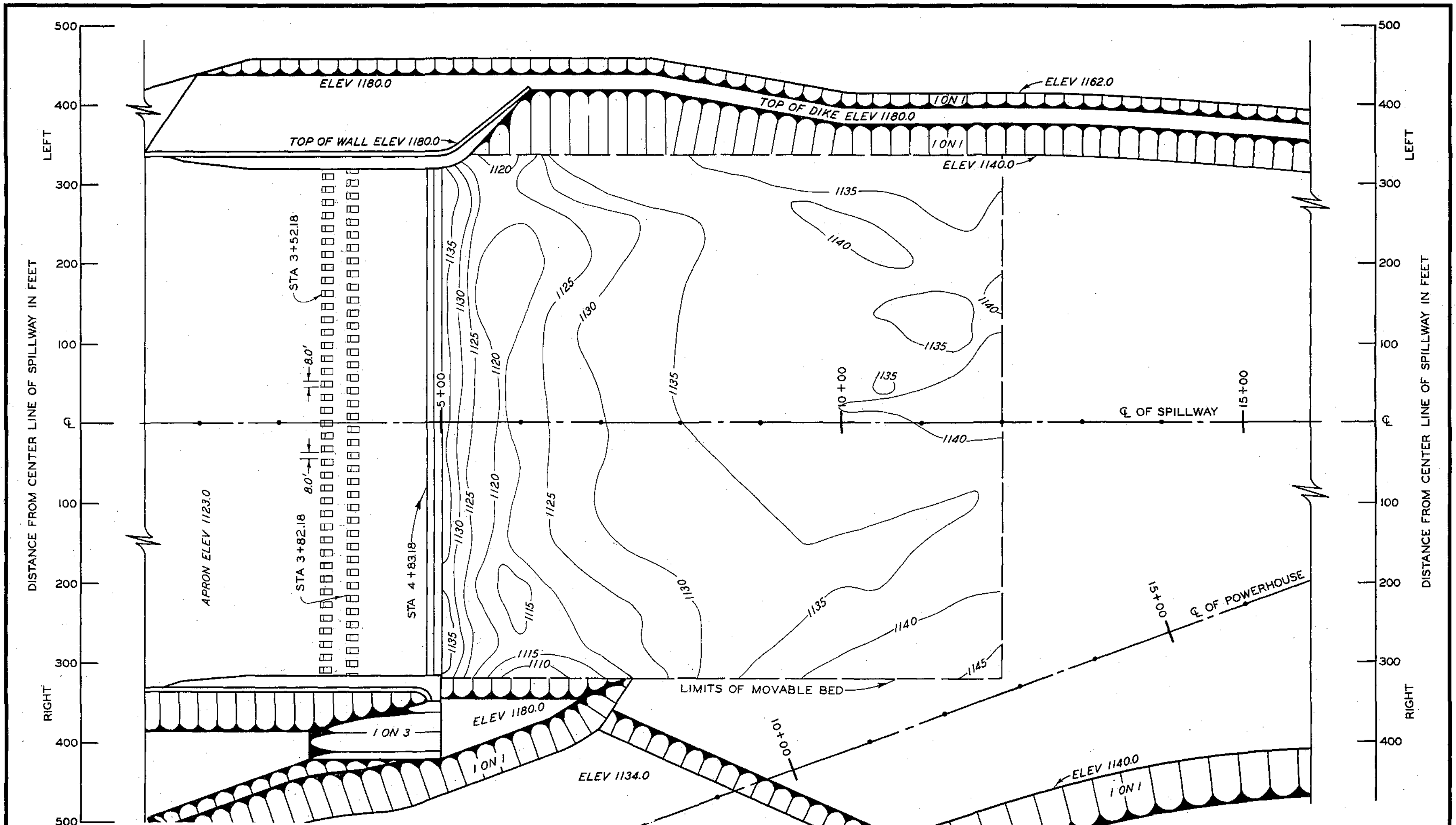
ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1132.0 PRIOR TO START OF TEST.

TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
9-FT END SILL - STA 4+94.18

SCOUR PATTERN
TYPE 1-B STILLING BASIN
DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

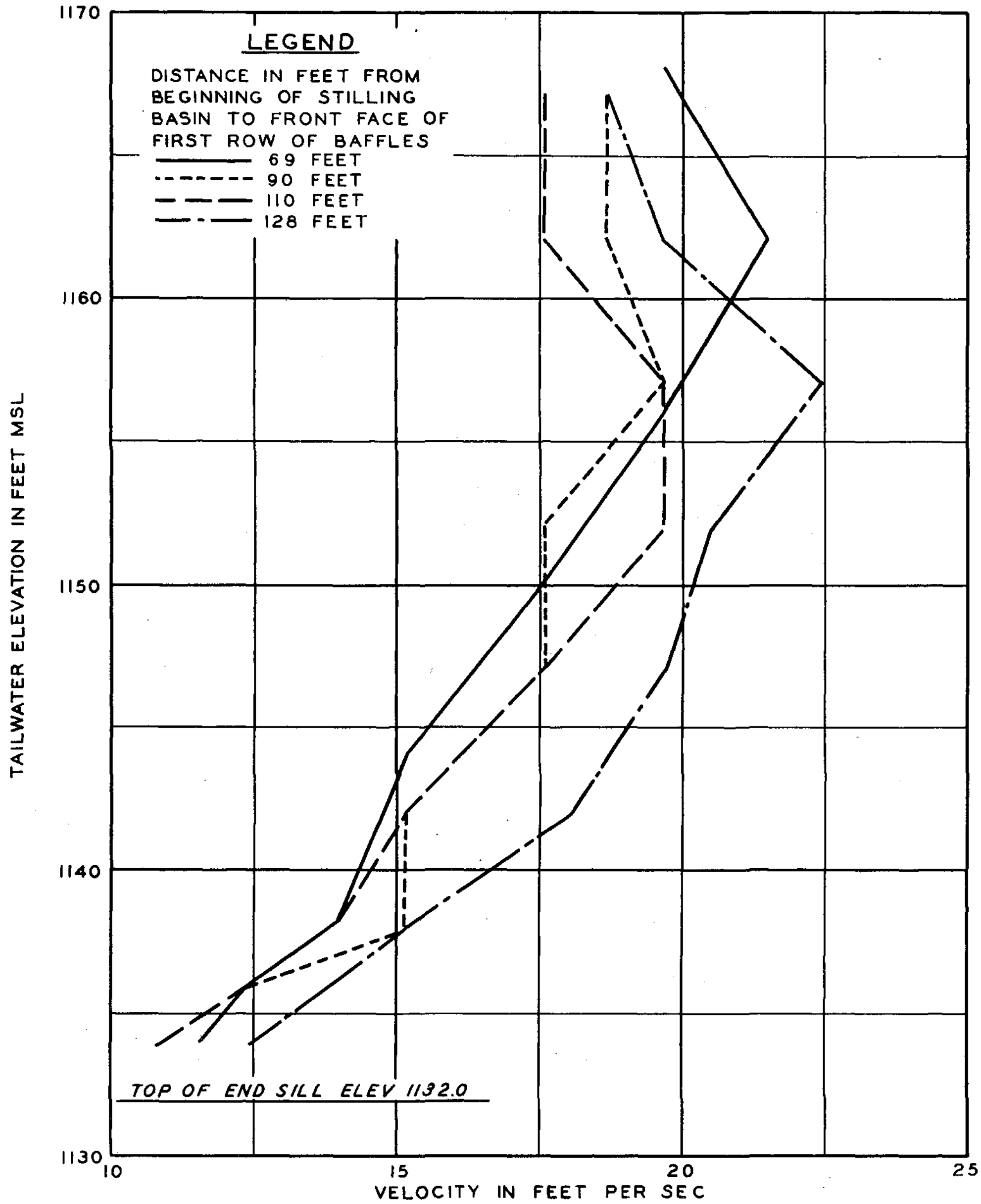
SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1137.0 PRIOR TO START OF TEST.

TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+82.18
14-FT END SILL - STA 4+83.18

SCOUR PATTERN

TYPE 1-C STILLING BASIN
DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT

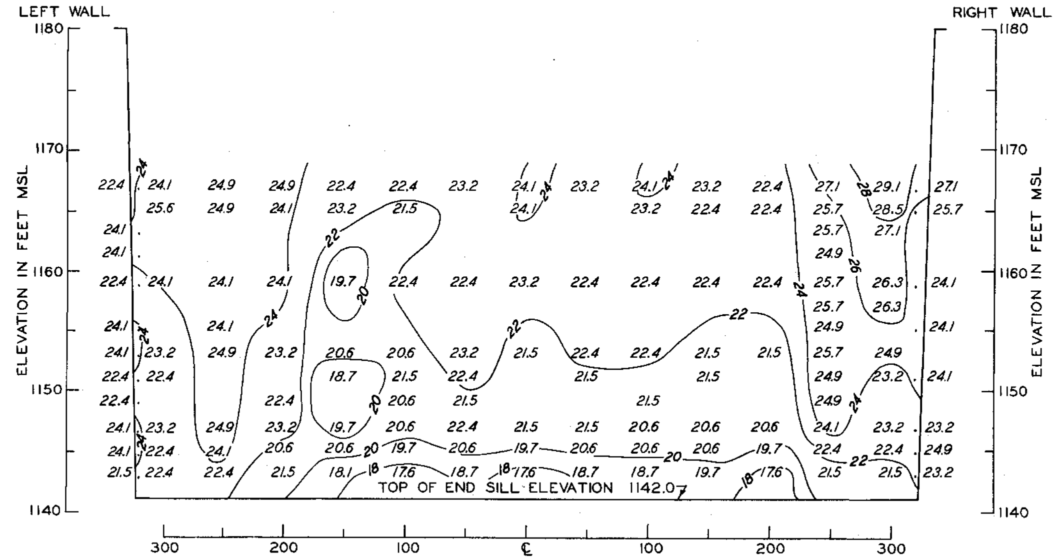


TEST CONDITIONS
Q = 364,000 CFS
TW = 1170.2

NOTE: BASIN LENGTH 220 FEET
BASIN ELEVATION 1123.0 FEET
END SILL HEIGHT 9 FEET

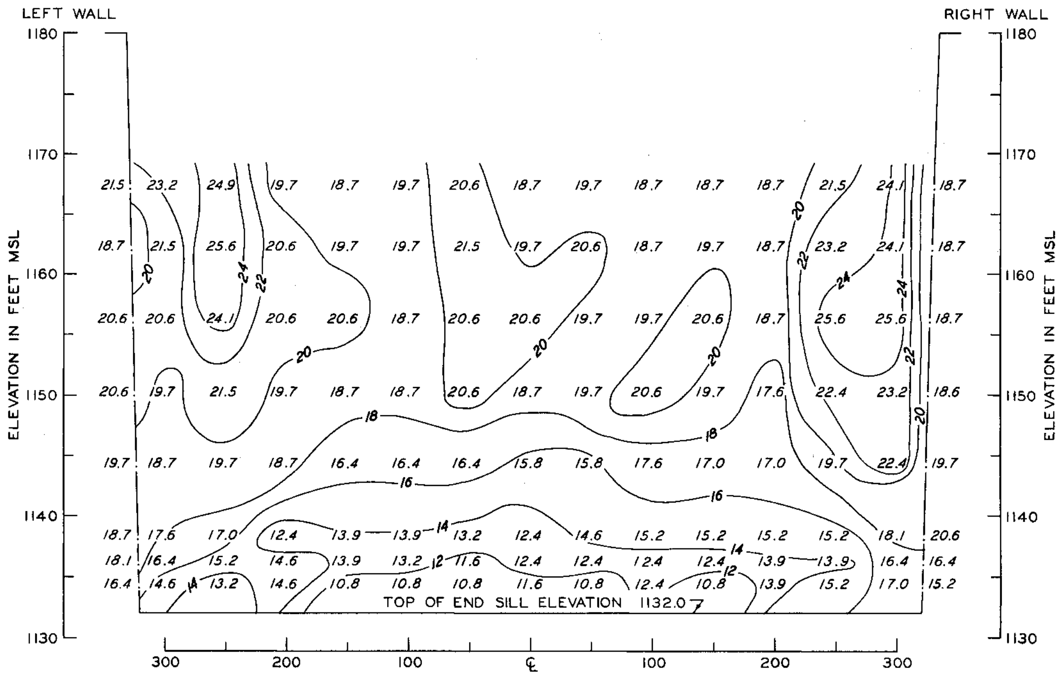
BAFFLES:
HEIGHT 8 FEET
ROWS 2
DISTANCE BETWEEN ROWS
18 FEET FRONT FACE TO FRONT FACE

BAFFLE PIER LOCATION VS VELOCITY AT END SILL



STATION 4 + 93.18

TYPE 3 DESIGN



STATION 4+58.68

TYPE 5 DESIGN

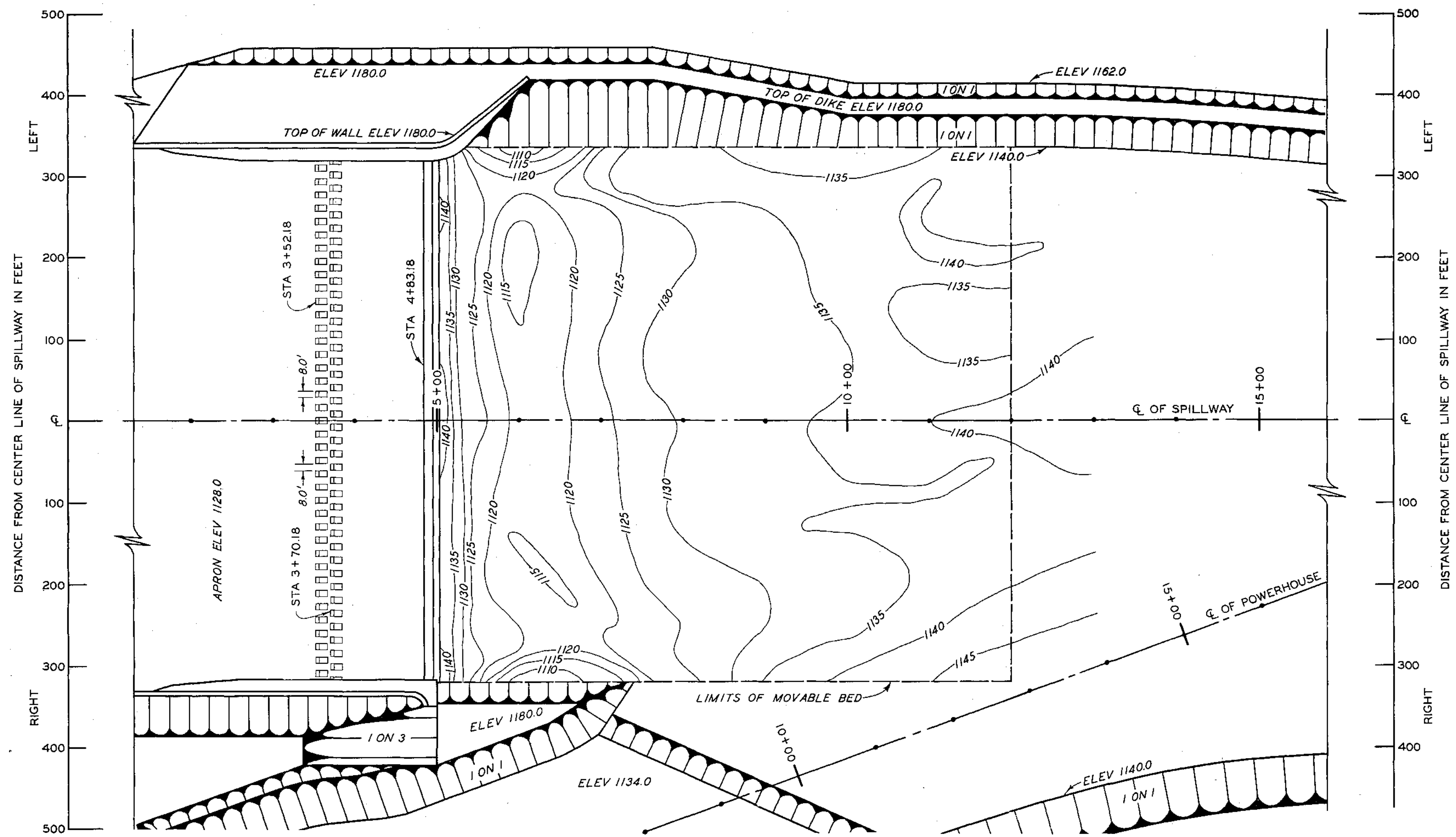
TEST CONDITIONS

DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT

NOTE: VELOCITIES ARE IN FEET PER SECOND IN PROTOTYPE

CROSS-SECTIONAL VELOCITIES OVER END SILL

TYPES 3 AND 5 DESIGNS



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

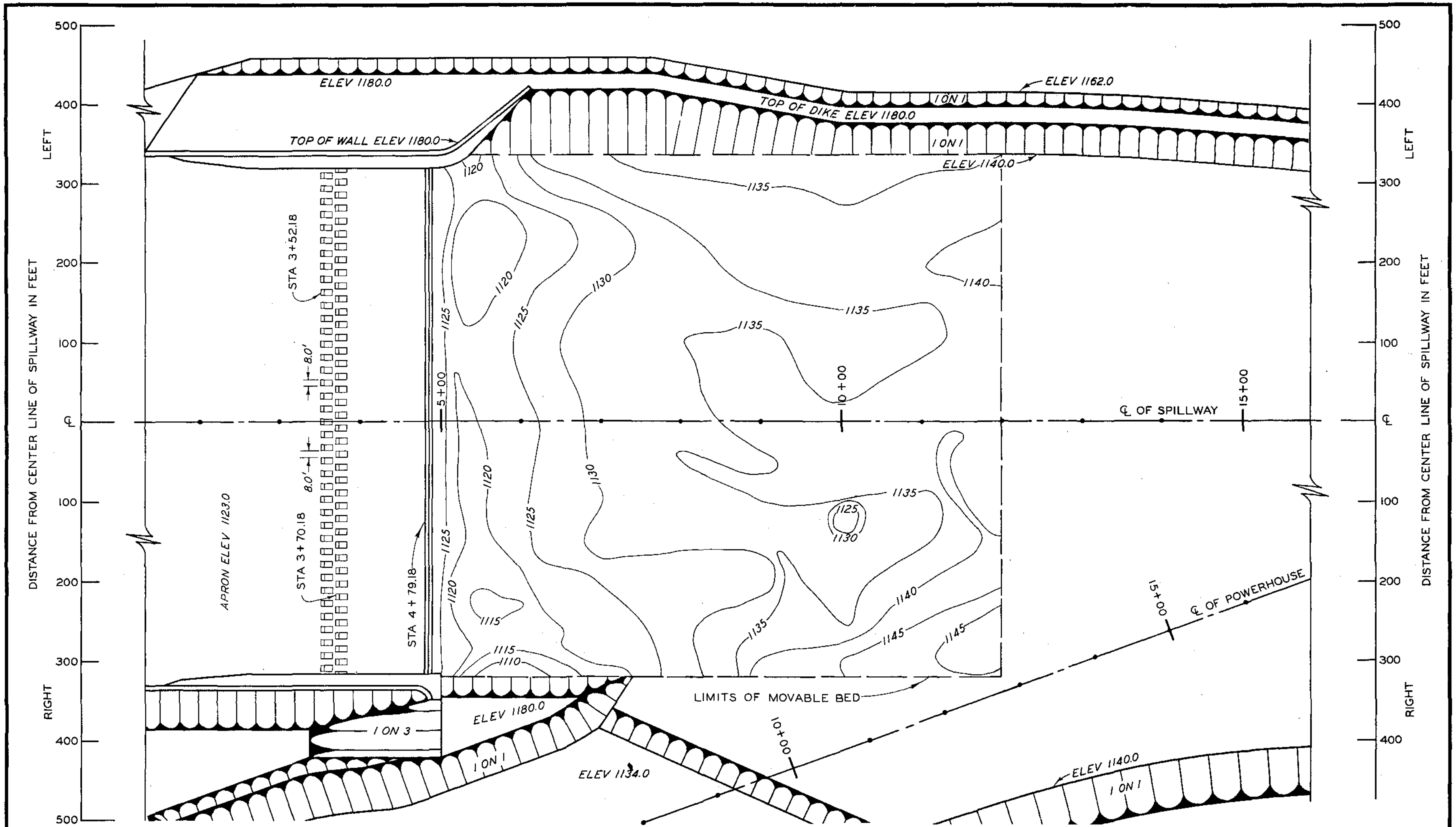
ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1137.0 PRIOR TO START OF TEST.

TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
14-FT END SILL - STATION 4+83.18

SCOUR PATTERN
TYPE 3 STILLING BASIN
DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1132.0 PRIOR TO START OF TEST.

TEST CONDITIONS

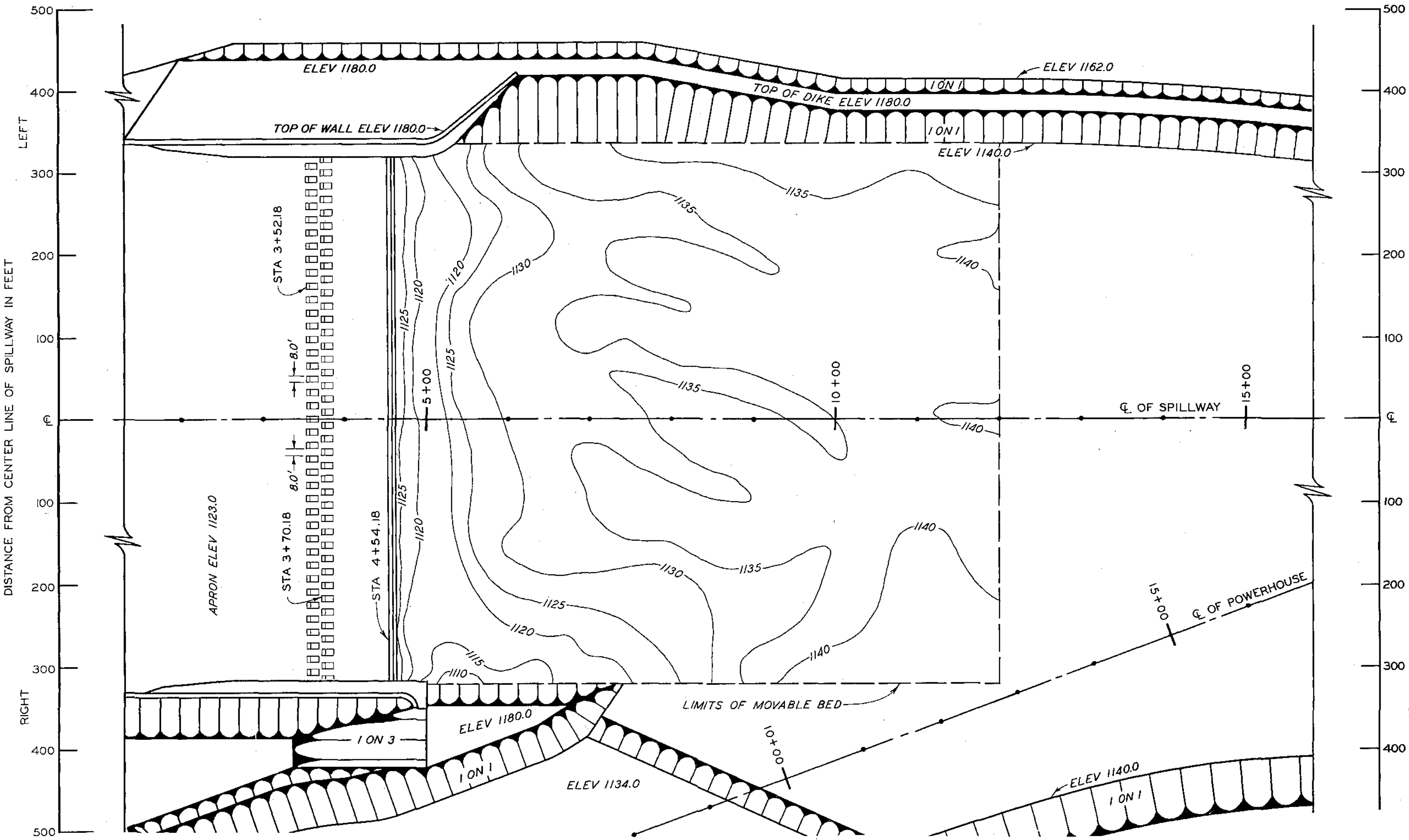
ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
9-FT END SILL - STA 4+79.18

SCOUR PATTERN

TYPE 2-B STILLING BASIN
DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT

PLATE 29

PLATE 30



NOTE: STATIONS ARE IN HUNDREDS OF FEET FROM SPILLWAY CREST.

ELEVATIONS ARE IN FEET REFERRED TO MEAN SEA LEVEL.

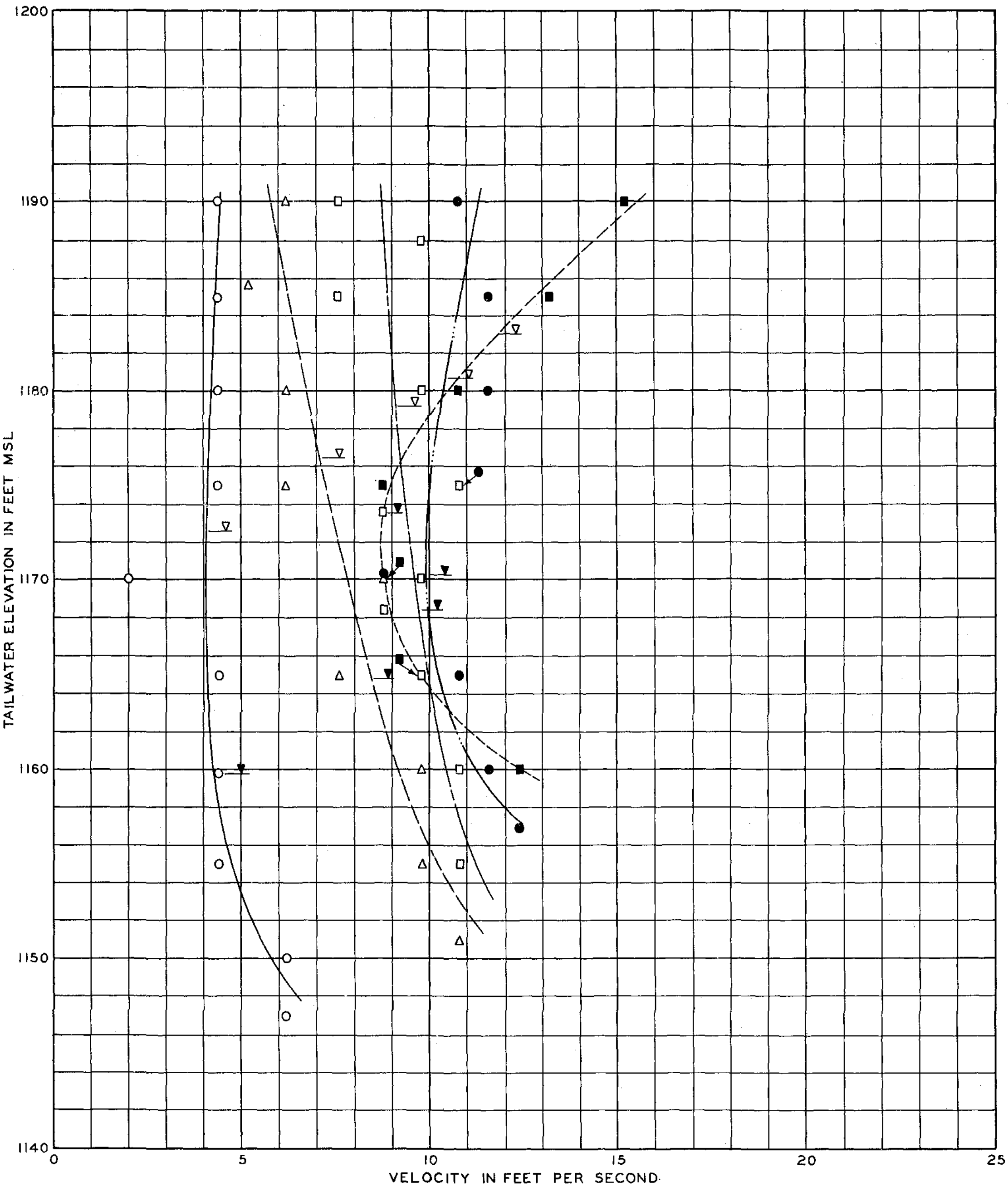
SAND MOLDED FLAT TO ELEV 1140.0 AND SLOPED ON 1-ON-10 SLOPE TO INTERSECTION WITH END SILL AT ELEV 1132.0 PRIOR TO START OF TEST.

TEST CONDITIONS

ROW OF 8-FT BAFFLES - STA 3+52.18
ROW OF 8-FT BAFFLES - STA 3+70.18
9-FT END SILL - STA 4+54.18

SCOUR PATTERN

TYPE 5 STILLING BASIN
DISCHARGE 364,000 CFS
TAILWATER ELEV 1170.2 FT



LEGEND

- Q= 100,000 CFS
- Q= 200,000 CFS
- Q= 300,000 CFS
- Q= 364,000 CFS
- Q= 500,000 CFS
- 1949-1950 TAILWATER ELEVATION
- ADVANCED DEGRADATION TAILWATER ELEVATION

NOTE: VELOCITIES MEASURED ON BASIN CENTER LINE 2 FT OFF TOP OF END SILL.

TAILWATER-VELOCITY CURVES

TYPE 5 STILLING BASIN